PSTRS14
Version 6.1

Prestressed Concrete Beam Design/Analysis Program

User Guide

Texas Department of Transportation

Bridge Division

Table of Contents

General Notation

b_w = Web width, or diameter of circular section

d = Distance from extreme compression fiber to centroid of tension reinforcement, in inches

E_c = Modulus of elasticity of concrete in ksi or MPa

E_s = Modulus of elasticity of reinforcement in ksi or MPa

f'_c = Compressive strength of concrete at 28 days

f'_{ci} = Compressive strength of concrete at time of application of prestress force (at release/transfer of prestress)

f_{pc} = Compressive stress in concrete (after allowance for all prestress losses) at centroid of cross section resisting externally applied loads or at junction of web and flange when the centroid lies within the flange. (In a composite member, f_{pc} is the resultant compressive stress at the centroid of composite section or at junction of web and flange when the centroid lies within the flange, due to both prestress and moments resisted by precast member acting alone.)

f_{pe} = Compressive stress in concrete due to effective prestress force only (after allowance for all prestress losses) at extreme fiber of section where tensile stress is caused by externally applied loads

f_r = Modulus of rupture; $7.5\sqrt{f'_c\,(psi)}$ for all design specifications except the AASHTO LRFD 6th Edition (2012) Specifications; $0.24\sqrt{f'_c\,(ksi)}$ for AASHTO LRFD 6th Edition (2012) Specifications

M_{cr} = Cracking moment

$M_{d,nc}$ = Mid-span non-composite dead load moment

M_i = Mid-span dead load moment(s) resisted by each S_i

S_b = Non-composite section modulus for bottom fiber of section

S_c = Final composite section modulus for bottom fiber of section

S_i = Section modulus resisting each M_i, for bottom fiber of section

V_{cw} = Nominal shear strength provided by concrete when diagonal cracking results from excessive principal tensile stress in web

w_c = Weight of concrete, lbs per cubic ft

β = Factor relating effect of longitudinal strain on the shear capacity of concrete, as indicated by the ability of diagonally cracked concrete to transmit tension.

θ = Angle (in degrees) of inclination of diagonal compressive stresses used in nominal shear resistance calculation

ϕ = Resistance factor

Chapter 1 – Introduction

Overview

The *Prestressed Concrete Beam Design and Analysis Program* (*PSTRS14*) is developed and maintained by the Texas Department of Transportation (TxDOT/Department). It incorporates the functions of five precursor systems and adds additional functionality. The general functionality of both the precursor systems and *PSTRS14* are discussed in this chapter.

The remainder of this user guide includes:

- Chapter 2, "Analysis and Design Considerations," discusses program capabilities and limitations;
- Chapter 3, "Description of Input," describes each input card, including its fields, input requirements, and defaults;
- Appendix A contains figures and tables;
- Appendix B contains examples of input for design and analysis problems; and
- Appendix C contains optional design input forms.

The term "grid" or "strand grid" used herein refers to all potential strand locations in a particular standard or non-standard cross section. The term "strand pattern" refers to the actual number and distribution of strands in the grid of a standard or non-standard beam that has been designed or is being analyzed. Strand grids are used in design problems for the potential locations and limits on strand placement while strand patterns are part of the outcome of design runs or input to analysis problems.

Precursor Systems

The first version of *PSTRS14* was released in 1990 having been developed by consolidating source code from five prestressed concrete beam design/analysis programs written in the 1970s by the Department. These programs were *PSTRS10*, *PSTRS11*, *PSTRS12*, *DBOXSS* and *DBOXDS*. These precursor systems were originally developed in the FORTRAN IV language for the IBM 360/XX series mainframe computers.

PSTRS10, *Prestressed Concrete Girder Design* performed calculations for the design of simple span I-shaped beams of pretensioned, prestressed concrete for use in highway and railroad bridges [1]. The program could be used to design standard I-beams and non-standard beams with cross-sections similar to current standard I-beams and was used for: (1) design of simple span beams for AASHTO or railroad loadings; (2) damage investigations; and (3) camber of prestressed beams.

PSTRS10 design capabilities were limited. Only stress-relieved strands were allowed. The strand pattern could be draped or straight, but not debonded. The program determined the composite and non-composite section properties, moments, shears, stresses, dead load deflections, web reinforcement, spacing, moment capacity, and prestressing strand patterns.

PSTRS11, Prestressed Beam Stresses and Camber was not fully incorporated into *PSTRS14*. This program predicted the stresses, strains and camber of any simple span prestressed cross-section for prestress and dead load only (live load was not considered). An empirical creep and shrinkage function based on limited research data could be varied for different fabrication environments. The effects after slab placement could also be evaluated.

PSTRS11 could be used for: (1) simple span prestressed beam analysis (of prestress and dead load only) of any cross-sectional shape; (2) loss and camber predictions for various beam and slab ages; and (3) stress and strain predictions for various beam and slab ages. The functionality which extended analysis to "any cross-sectional shape" was the only *PSTRS11* specific functionality incorporated into *PSTRS14*. *PSTRS11* is discussed further in the section, **Estimated Camber at Erection**.

PSTRS12, Prestressed Beam Analysis was a prestressed concrete beam analysis program used to check optional beam designs when given the end and centerline strand patterns and other design parameters. Required concrete strength and moment capacity were computed and compared to those provided. Total camber was predicted based on an empirical procedure [1]. This program had the same limitations as *PSTRS10*, except that low-relaxation strands were subsequently added as an option to stress-relieved strands. In addition to checking optional/alternative beam designs for compliance with design allowable stresses and flexural strength, PSTRS12 could be used to evaluate damaged beams.

DBOXSS and *DBOXDS* were written to design pretensioned, prestressed concrete box beams with straight strands and draped strands, respectively. The programs used a linear programming procedure to create a least cost design using standard beam shapes or user defined sections. The programs determined the release and 28 day strengths for the minimum number of strands [1].

<u>PSTRS14</u>

PSTRS14 incorporates selected functionality and essential logic of *PSTRS10*, *PSTRS11*, *PSTRS12*, *DBOXSS* and *DBOXDS* and adds enhanced capabilities including accommodation of *AASHTO Standard specifications* thru the 17th Edition (2002) [2] and LRFD specifications through the 6th Edition (2012)[1] of the *AASHTO LRFD Bridge Design Specifications* [4,5,6] and including, as user options, the following four prestress loss calculation procedures:

- For AASHTO Standard Spec design,
  a. the loss procedures of the 15th Edition (1994 Interim) thru 17th Edition (2002) [2];

[1] The development of *PSTRS14 Version 6.0* predates the publications of the 2014 Interim Revisions 7th Edition (2014) *AASHTO LRFD Bridge Design Specifications* and the Interim Revisions thereto. Among the changes to 6th Edition included in the 7th Edition were changes to the E_c equation, to the development formulas and to the concrete stress block factor for $f'_c > 10$ ksi. Therefore, sound engineering judgment must be used when applying this program to highway bridges designed, or being designed, in accordance with the 7th and later editions of the AASHTO LRFD BDS. However, this program remains useful for preliminary design, development of new beam sections, life cycle camber evaluations and other investigations. The unique capability of *PSTRS14* Version 6.0 is that it can be used to design or analyze prestressed concrete bridges in accordance with over 23 years' worth of AASHTO highway bridge design specifications as well as in accordance with the 2006 AREMA railroad bridge specifications.

- For *AASHTO LRFD Bridge Design Specifications* designs,
    b. the loss procedures of the 3rd Edition (2004) of LRFD [3];
    c. the loss procedures introduced in the 4th Edition (2007) and included subsequently in the 5th Editions (2009) and 6th Edition (2012) of LRFD [4,5,6]; and
    d. the loss formulations reported in the findings of TxDOT Research Project 0-6374 [7].

The capability of PSTRS14 to use these design specifications and especially the related prestress loss calculation procedures as implemented in *PSTRS14* should not be construed as a design policy of TxDOT. For design policy please see the **TxDOT Bridge Design Manual** – **LRFD** [8].

PSTRS14 may be used to design and analyze standard I beams, Box beams, Double-T beams, U beams, Slab beams, Decked Slab Beams, TxGirders, X-Beams and user defined non-standard beams with low-relaxation or stress-relieved strands, in accordance with current *AASHTO Standard Specifications* [2], AASHTO LRFD Specifications [4,5,6] or AREMA Specifications [9]. In addition to the design specification related options, numerous user options are available to define specific concrete and steel materials, properties of beams, slabs, shear keys, and non-standard composite regions.

Error checking, warning, and informative messages are printed to the output files to capture design solution information, deficiencies and other information about the beam being designed or analyzed as well as fatal and non-fatal errors for the most common problems encountered during program execution. These alert the user to potential problems caused by making input mistakes or exceeding allowable limits, etc.

The program is applicable only to the design or analysis of simple-span pretensioned concrete beams having draped or straight strand patterns using standard seven-wire strands. Straight strand patterns may be debonded, but draped strand patterns must be fully bonded. Although several beams can be defined in a single *PSTRS14* run, the program does not design/analyze a system of beams and thus the live load distribution factors for LRFD Specification designs must be input by the user on a per beam basis.

The design algorithm of *PSTRS14* performs a simultaneous solution of both the required strand pattern (the number and distribution of strands in the cross section along the beam length) and the required release and final concrete strengths. Some other programs assume or require the user to input the release and final concrete strengths, and/or do not generate an optimum strand pattern but rather rely on the user to define the strand pattern or otherwise do not reach an optimum solution. For such programs, if the user assumes, for example, too low a final concrete strength, the number of strands required to reach a solution may be higher than would be required if a higher concrete strength were assumed or a solution may not be reached if final compression controls the concrete strength required. Also, for such programs the specified release strength may be inadequate for the number of strands required, resulting in no design solution being achieved or, in the case of partially debonded straight strands, in a design solution having a prohibitively extensive debonding scheme to alleviate end zone stresses.

With the implementation of a total of three prestress loss procedures for LRFD design/analysis in Version 6.0 of *PSTRS14* the design solution can vary with the loss method assumed. This may result in a significant difference in the number of strands and/or concrete strengths required with all other input parameters being equal. This is because the AASHTO LRFD 4th Edition (2007) and TxDOT Research Project 0-6374 losses are more sensitive to release strength than are the AASHTO LRFD 3rd Edition (2004) losses and typically result in less total prestress loss, in some cases a lot less.

Units of Measure/Calculation

This program and its precursors were written assuming English (Imperial) units are used for input and furthermore that concrete strengths are input in psi units. Metric (SI) units have been accommodated by converting metric input to English units (soft conversion in), performing all calculations in these soft converted English units, and then converting the calculated English values to metric units for output (soft conversion out) if the user so chooses. Thus, the non I/O calculations of the program are performed using English units, and values are typically referenced in English units in this guide. When English units are specified for input, concrete strengths must always be input in psi units and output listings are output in psi units, except in the case of reports created for CAD import (i.e. .smd and .sms files) for LRFD. When the governing design specifications are LRFD the file created for CAD import lists concrete strengths in ksi units. Regardless of the system of units of input and output, the program internally stores and performs calculations using stress magnitudes in ksi units.

For empirical formulae involving the square root of concrete strength, (i.e. the formulae for the modulus of elasticity of concrete and for tensile stress limits) the leading coefficients (a.k.a. the “multipliers”) are dependent on the units of the concrete strength, and so are different magnitudes for psi (English) units as compared with both MPa (Metric) units and ksi (English) units; however, for all but the AASHTO LRFD 6th Edition (2012) Specifications, empirical formulae based on psi (English) units are used internally by the program. For AASHTO LRFD 6th Edition (2012) Specifications only the ksi (English) unit compatible coefficients are assumed for internal calculations and, when input by the user, these coefficients must be based on concrete strengths in ksi units. As stated previously, the concrete strengths remain in psi units for input and output, except as noted for the CAD reports. This somewhat confusing situation is an unfortunate legacy of *PSTRS14*’s accommodation of multiple design specifications and units of measure and of its fairly robust level of backward compatibility with user input data files created for previous releases of the program.

When input is discussed in Chapter 3 – Description of Input, the units for each value to be input, as well as the defaults, are shown in both metric and English systems. The units are also clearly shown in the output files, except for the output files created for CAD import. For these files the units are shown on the TxDOT standard sheet for Non-Standard Designs (one for each beam type) published in the Bridge Division’s CAD standard plans collection.

The format of the CAD output reports for inclusion on the Non-Standard Beam Design sheets does not comport with the new design algorithm, first fully implemented in PGSuper v2.9.1, that considers straight strand bonded, straight strand partially debonded and draped strand designs and picks the optimum one, with advantage being given to straight strand patterns.

Chapter 2 – Analysis and Design Considerations

Design Specifications

The analyses and designs produced by *PSTRS14* are based on currently accepted design procedures used by TxDOT. The procedures conform, in general, to the following design specifications:

- *AASHTO Standard Specifications for Highway Bridges* (thru 17th Edition – 2002) [2].
- *AASHTO LRFD Bridge Design Specifications* (thru 4th Edition – 2007) [4].
- *AASHTO LRFD Bridge Design Specifications* (5th Edition – 2009, plus 2010 Interim) [5].
- *AASHTO LRFD Bridge Design Specifications* (6th Edition – 2012)[2] [6].
- *American Railway Engineering and Maintenance-of-Way Association (AREMA) Specifications* (2006) [9].
- *American Standard Building Code Requirements for Reinforced Concrete* (1989), ACI 318-89 [10]. Used as an option in shear design only.

Allowable Stresses

The following stress limits are used in *PSTRS14* for the indicated service load combinations per the provisions of the specifications indicated:

Service Load Combinations[3]

COMB1. DL + PS + (L + I)	COMB3. (DL + PS)/2 + (L + I)
COMB2. DL + PS	COMB4. DL + PS + 0.8*(L + I)

Compression Stress Limits

Specification	At Release	In Service (Final)	Load Combination
All Specs	$0.65\,f'_{ci}$		Not Applicable
AASHTO 94 & AREMA		$0.40\,f'_c$	COMB1 & COMB2
AASHTO 95		$0.60\,f'_c$	COMB1
		$0.40\,f'_c$	COMB2
		$0.40\,f'_c$	COMB3
AASHTO LRFD 05		$0.60\,f'_c$	COMB1
		$0.45\,f'_c$	COMB2
		$0.40\,f'_c$	COMB3
AASHTO LRFD 09 & 12		$0.60\,f'_c$	COMB1
		$0.45\,f'_c$	COMB2

2 See footnote 1 in Chapter 1 – Introduction.
3 In the ***PSTRS14 User Guides*** for releases 5.0, 5.1 and 5.2 the load combination equations for COMB1 and COMB2 shown in this section were erroneously switched.

Tension Stress Limits

(see *Note* regarding units of concrete strengths)

Specification	At Release	In Service (Final)	Load Combination
AASHTO SS & AREMA	$7.5\sqrt{f'_{ci}}\,(psi)$	$6.0\sqrt{f'_{c}}\,(psi)$	COMB1
AASHTO LRFD 09	$7.5\sqrt{f'_{ci}}\,(psi)$	$6.0\sqrt{f'_{c}}\,(psi)$	COMB4
AASHTO LRFD 12	$0.24\sqrt{f'_{c}}\,(ksi)$	$0.19\sqrt{f'_{c}}\,(ksi)$	COMB4

Notes:

- "Release" refers to the initial conditions at transfer of prestress force, and "Final" refers to the final in-service conditions (i.e., 28-day concrete strengths and final service loads and losses). Starting with PSTRS14 v5.0, the user has the option of entering the compressive stress allowable limit at release. Prior to v6.1, the PSTRS14 default compressive stress limit at release was 0.60 as currently provisioned in all AASHTO LRFD Bridge Design Specifications. In v6.1, this limit defaults to 0.65 to reflect the results of TxDOT sponsored research [11] and the TxDOT design policy that implements these results [8].
- Concrete strengths f'_{ci} and f'_{c} in the tension formulae are assumed to be input in psi units for all design specifications except AASHTO LRFD 12 where they are assumed to be input in ksi units. Thus, if the user selects the AASHTO LRFD 12 design specifications all user input of concrete strength shall be in ksi units and any multipliers input on the MAT1 and/or SPEC cards shall be those that comport with concrete strengths in ksi units.

AASHTO 95 stress limits are applicable to 1995 thru 2002 Editions/Interims of the Standard Specifications (AASHTO SS) [2], while AASHTO 94 stress limits are applicable for 1994 and prior Editions/Interims of the AASHTO SS. AASHTO LRFD 05 stress limits are applicable to all relevant Interims/Editions of the LRFD Bridge Design Specifications, 4th Edition through 2008 [4]—with tensile stress limit formulae based on concrete strengths in psi units. AASHTO LRFD 09 stress limits conform to the 2009 Interim Revisions of the LRFD Bridge Design Specifications, 4th Edition, and to the 5th Edition (2010) thereof [5]—with tensile stress limit formulae based on concrete strengths in psi units. AASHTO LRFD 12 stress limits conform to the LRFD Bridge Design Specifications, 6th Edition (2012) [6]—with tensile stress limit formulae based on concrete strengths in ksi units.

When the user chooses not to consider the effects of the length over which prestress is transferred into the beam (as is the case for releases of *PSTRS14* prior to version 6.0 as there were no provisions in those releases of the program to fully consider this parameter), the final compressive stress in the end of a beam without debonding is not allowed to control final concrete strength. The rationale for ignoring beam end stresses given in previous user guides published for prior releases of *PSTRS14* are as listed below (the words in brackets, {}, have been added to this user guide for version 6.0 for clarification):

- The most severe {i.e., highest} compressive stress occurs at release {of prestress} when the concrete strength is lower and the prestress force is higher.

- The program {prior to version 6.0 and when running version 6.0 but ignoring transfer length} does not account for the partial {transfer of prestress force} at the center of bearing—the assumed beam end in *PSTRS14* {prior to version 6.0 and when running version 6.0 but ignoring transfer length}—except in the case of shear related calculations. Instead, the program {prior to version 6.0 and when running version 6.0 but ignoring transfer length} conservatively applies full prestress force at this location.
- The difference between the allowable versus actual stresses at final and at release {was assumed to be} less than the error for all practical values of beam end projection past the centerline of bearings. Final compressive stresses are, therefore, checked beginning at 0.1L for beams without debonded strands and at the end of the beam for beams with debonded strands {prior to version 6.0 and when running version 6.0 but ignoring transfer length}.
- {When coding the program to consider the effects of transfer length, the programmer found and fixed a bug in the source code that had, for all releases prior to version 6.0, resulted in the program erroneously using the strand stress at release of prestress as the stress in the strands at final and so the calculated "severe compressive stress" was erroneously high, with the result of TxDOT having to establish the policy of ignoring the stress when determining final concrete strength required}.

When the user chooses to consider the effects of the length over which prestress is transferred into the beam (as is provided for in version 6.0) the final compressive stress at the physical end of a beam is zero and the maximum calculated beam fiber stress at points between the beam end and the point of full transfer of prestress, inclusive, is allowed to control final concrete strength, a much more rational approach than simply ignoring the stress.

Analysis Mode

Analysis versus Design Modes

PSTRS14 can operate in either design or analysis modes. When in analysis mode, a design is not produced for output. Thus, specified strand pattern and concrete strengths are input by the user. Prestress stresses (before losses) resulting from the analysis are a direct result of these user input values rather than from any design processes such as the design algorithm adding strands or bumping up concrete strengths. Losses are affected by both input and default dead loads.

In analysis mode, certain design-check ratios (e.g. user input concrete strengths and required minimum flexural capacity, divided by the calculated required concrete strengths and calculated flexural capacity, respectively) are output. Each of these ratios is based on input values divided by the corresponding calculated values listed below:

a. Calculated flexural demand (factored moment, based on loading) – flexural demand (factored moment) based on user input of live and dead loads and intrinsic dead load of beam and slab;
b. Calculated flexural capacity ("ultimate moment" provided) based on cross section, concrete strength and strand pattern;

c. Controlling concrete release strength, f'_{ci}, is the maximum of that required at mid-span, endpoint (centerline of bearing when transfer length is not considered, or at the point of full prestress transfer when transfer length is considered), at hold-down-point, and 4.0 ksi or the strength, if any, input by the user on the MAT1 card. Except for the minimum values of 4.0 ksi and the strength input by the user on the MAT1 card, these strengths are determined by solving the allowable stress formulae for f'_{ci}, using as input the initial stress in the concrete in the top and bottom of the beam due to prestress force, strand eccentricity, and beam weight. No scaling of stresses is required, as all the loads are known at time of prestress transfer.

d. Concrete, f'_c, is the maximum that is required to meet compressive allowable or that is needed to meet tension allowable. Applied stresses are scaled (see Scaling of Stresses for Analysis Mode) by the ratio of design stresses (input by the user) to calculated stresses produced by the assumed loads. Compression controlled f'_c is based on the scaled maximum of either top or bottom final beam compressive stress under all pertinent combined loads. Tension controlled f'_c is based on the scaled maximum tensile stress of either top or bottom beam final tensile stress under all pertinent combined loads.

Overview of Analysis Mode

In analysis mode, *PSTRS14* 1) evaluates the defined beam, based on the user's input parameters, including applied loadings, provided strand pattern, provided concrete strengths, design stresses from the original design, and required minimum flexural capacity (called "ultimate moment" in program output though flexural capacity, a.k.a. flexural resistance, is the term used in LRFD), and 2) calculates required concrete strengths based on beam stresses at both release and final stages.

The program computes the required concrete strengths, based on 1) load combination stresses– scaled as described below under the heading *Scaling of Stresses for Analysis Mode*, and 2) the allowable stress factors corresponding to each load combination. The program determines the ratios: input values for provided f'_c and f'_{ci} divided by the corresponding computed required concrete strengths. The program also computes the ratio of flexural capacity provided with the value the user inputs as the design value for required minimum flexural. If the analysis shows that any of these ratios is less than 1.0, the message "BEAM DOES NOT SATISFY DESIGN REQUIREMENTS" is included in the output, followed by messages describing the deficiencies. That these ratios are less than 1.0 is not the only trigger for this program generated message. The user should review the deficiencies and their magnitudes to determine whether they are significant or can be ignored.

Included as "design deficiencies" are ratios of user input beam top and bottom fiber design stresses to PSTRS14 calculated total external load top and bottom fiber stresses, along with the ratio of input flexural demand (user's input of "ultimate moment" required) to PSTRS14 calculated flexural demand, when any of these ratios are less than 1. However, these "design deficiencies" are only warnings, not fatal design deficiencies. They are indications that the design data values entered are less than the values calculated by the analysis, and thus that the user should check that appropriate design values have been input. On the other hand they could be indicative of an error in the original design of the beam.

Scaling of Stresses for Analysis Mode

Because the dead load of the analysis may be less than that which is assumed in the engineer's original beam design, the analysis scales the calculated stresses by ratios of design stresses (input by the user) at mid-span to the corresponding calculated top and bottom stresses at mid-span. Thus, *PSTRS14* analyzes the beam in the following fashion to account for differences between the engineer's design loading and the loading input by the user performing an analysis, and also to check locations other than the centerline and ends of the beam—especially for cases with debonded strands. The controls for the analysis are the user entered top and bottom fiber design stresses at mid-span. The program determines the ratio of the entered top fiber design stress at the mid-span to the computed top fiber stress at mid-span based on applied loads. The computed applied-load top fiber stress (excluding stresses from the prestress "load") at each analysis location along the beam is then multiplied by this ratio to obtain an approximation of the stress at each location that the beam would have been originally designed for. The same procedure is carried out for the bottom fiber stress.

General Notes on Analysis Mode

The maximum allowed shear steel spacing, flexural demand (moment due to factored loading), and dead load deflections are based on the analysis performed by *PSTRS14* and are not adjusted by the entered top and bottom fiber design stresses. Therefore, unless the program's calculated beam top and bottom fiber stresses due to total external loading are close to the design values entered, the shear design, ultimate moment required due to loading, and dead load deflections will not correspond exactly to the beam being analyzed.

The camber of the beam being analyzed and the camber of a previously designed beam can be compared by use of the ACAM card. When the ACAM card is used, either entry of the beam modulus of elasticity, E_c on the MAT1 card or entry of the beam f'_c on the ACAM card (used in the calculation of the beam E_c) is required. This is because the E_c of the beam is needed in the camber calculation of the previously designed beam. Note that this camber is computed using a single value of E_c so the effect of the difference between initial and final E_c (or E_{ci} and E_c) cannot be modeled by *PSTRS14* in analysis mode.

A negative sign, indicating tension, must be entered for the bottom fiber design stress.

Beam Fabricators' Optional Design Input

Optional Design Input Forms

Special input forms are available for the evaluation of beam fabricators' optional design (see Appendix C – Optional Design Input Forms), which is performed in the analysis mode. Data is entered in the fields shown for each card on the forms, and only the cards and fields shown on the forms are to be used for this option.

There are four optional design input forms:

- Standard Beams with Draped or Straight Strands,
- Standard Beams with Partially Debonded Strands,
- Non-Standard Beams with Partially Debonded Strands, and
- Non-Standard Beams with Draped or Straight Strands.

BEAMF Card

Placing "F" in column 5 of the "BEAM" card (thus yielding "BEAMF"), results in a special output format intended only for use by fabricators performing optional designs and/or reviewers of such optional designs. This special output contains abbreviated optional design evaluation results as compared with the extensive output that is generated when "BEAM" and "ANAL" cards are specified. The BEAMF card must be placed in the position shown on the Appendix C – Optional Design Input Forms, whereas the BEAM card is typically placed at the end of the input data set. Thus, you cannot run an analysis using a BEAM card and then place an "F" in column 5, submit the input file again and expect the two outputs to correspond to each other. In fact, the "F" in column 5 of a BEAM card, as that card is normally placed, will produce erroneous results. Lastly, an input file with a BEAMF card must always end with an ACAM card.

Design Mode

PSTRS14 employs both user input data and an internal library of standard beam sections and other default values to perform design or analysis functions. This section discusses the functionality and limitations of the program in design mode. Much of this also applies to beams in analysis mode.

Standard Beam Cross Sections

PSTRS14 is coded with an internal library of standard beam/girder cross sections which allows the user to simply input on the BEAM card the pre-set designation for the beam/girder cross section type desired. These standard cross sections are described below in order of their introduction into PSTRS14.

Standard I Beams

Figure 1 – Standard I Beam Cross Section Properties, Figure 2 and Figure 3 show the TxDOT and AASHTO standard I beam section dimensions, properties and strand grids.

Standard Box Beams

Figure 4, Figure 5 and Figure 6 show the TxDOT and AASHTO standard Box beam properties and strand grids.

The standard Box beam section has shear key concrete included by default. The width of the joint is included in the shear key properties and is calculated as the beam spacing minus the bottom flange width. The contribution to the composite section of shear key concrete is determined at run time using the shear key definition illustrated in Figure 7. However, the shear key concrete can be eliminated using the OPTL card.

For center-to-center bearing lengths greater than 100 feet, the 4B40 and 5B40 Box beams have a 5" triangular chamfer on the inside of the bottom corners of each beam and an additional capacity of six strands. A note indicating this is printed in the output to the right of the beam type.

Standard Double-T and Heavy Double-T Beams

Standard Double-T beam section dimensions, properties and strand grids are included in the *PSTRS14* internal data library. See Figure 8, Figure 9 and Figure 10 for the dimensions, properties and strand grids of these cross sections.

Standard U Beams

Standard U Beam section dimensions, properties and strand grids are included in the *PSTRS14* internal data library. The internal diaphragms are handled automatically by the program by placing a point (concentrated) dead load on the non-composite section 10 ft. from either side of the beam span centerline. This load is 2.0 kips for U40 beams and 3.0 kips for U54 and is assumed present at time of the release of prestress. See Figure 11 and Figure 12 for the dimensions, properties and strand grids of these cross sections.

Standard Slab Beams

Standard Slab beam section dimensions, properties and strand grids are in the *PSTRS14* internal data library. See Figure 13 for the dimensions, properties and strand grids of these cross sections.

Standard TxGirders

Figure 14 and Figure 15 show the TxDOT standard TxGirder section dimensions, properties and strand grids. The Standard TxGirder is a special I beam shape that has been optimized for production and use in Texas.

Standard Decked Slab Beams

Standard Decked Slab beam section dimensions, properties and strand grids are included in the *PSTRS14* internal data library. See Figure 16 for the dimensions, properties and strand grids of these cross sections.

Standard X Beams

Standard X beams are standard Box beam shapes having strand grids with a third row of strands in their bottom flanges. As a consequence the bottom flange is 2 inches thicker in an X beam as compared with the standard Box beam from which it is derived. The extra row of potential strand locations provides for additional capacity needed to spread the beams out to support a full depth slab like other spread type beam sections (I beams, U beams, TxGirder and Decked Slab beams) are intended to support. See Figure 17, Figure 18 and Figure 19 for the dimensions, properties and strand grids of these cross sections.

Non-Standard (User Defined) Beam Cross Sections

A user defined beam shape may be modeled by using the non-standard “NS” beam type designation. Non-composite cross section (NSCS) cards are employed to specify cross section properties for non-standard (user defined) beams. The CPR1, CPR2 and CPR3 cards can be used to specify haunch, shear key and any other component that will become part of the composite section.

The “SERVICEABILITY” entries on the NSCS, CPR1, CPR2, and CPR3 cards are used in the calculations of beam stresses to compare with allowable concrete stresses and thus to determine release and final concrete strengths required based on these “serviceability” requirements. The “ULTIMATE” entries on these cards are used to define horizontal and vertical dimensions of the section for the flexural capacity calculations. For these calculations, the beam and composite sections are composed of a number of rectangular sections (defined by each set of horizontal and vertical dimensions) that approximate the actual cross section. The user must exercise judgment in determining appropriate entries to approximate the actual section.

PSTRS14 assumes that the non-composite section is the NSCS section (the beam) alone, and that the composite section is the total final composite section. That is, it assumes that the NSCS section resists the CPR1 dead load and other non-composite dead loads, that the NSCS/CPR1 composite section resists the slab dead load, and that the NSCS/CPR1/slab composite section resists the CPR2 dead load.

Likewise, *PSTRS14* assumes that the NSCS/CPR1/slab/CPR2 composite section resists the CPR3 dead load and that the NSCS/CPR1/slab/CPR2/CPR3 composite section resists composite dead loads. Any of the above dead loads may be absent and all those present will be treated as described above.

The slab thickness entry on the BEAM card is used to include the slab as part of the section and to determine the slab load. The haunch width and depth at centerline entries on the OPTL card are used to include the haunch. If a haunch is entered on the OPTL card and no slab thickness is entered on the BEAM card, the CPR1 card is assumed to be the slab, and the haunch is assumed to be part of it. In this case, only one CPR1 card is allowed, and values must be entered in all fields.

If CPRx (CPR1, CPR2, or CPR3) cards are entered in composite region sections, the total depth of composite region x is determined as follows: If LUD is the largest ultimate depth, y_b + 0.5x (maximum depth of compression zone), and SUD is the smallest ultimate y_b - 0.5x (maximum depth of compression zone for composite region x), then the depth of composite region x is the LUD minus the SUD. Therefore, one of the ultimate "maximum depth of compression zone" entries for the CPRx must go to the bottom of the total composite section of that composite region. See Figure 7 for an example of the entries required for the program to correctly calculate the depth of a Box beam shear key that has been entered on the CPR1 cards.

For the f_{pc} calculation in the V_{cw} shear capacity equation (AASHTO Standard Spec and AREMA Spec design only), the location of the top of the web is determined by taking the y_b + 0.5x (maximum depth of compression zone) from the NSCS card having the smallest width of compression zone, and that distance is taken as the maximum composite y_b used in the check for the f_{pc} calculation. If more than one NSCS card contains the same smallest width of compression zone, the first card encountered with that width is used.

Estimated Camber at Erection

The maximum camber calculations are derived from the hyperbolic function method developed by Sinno [12]. Sinno formulated hyperbolic functions for unit shrinkage and unit creep from field data of full-sized, Texas Type B, prestressed concrete bridge beams. The prestressing steel for the beams consisted of seven wire 7/16-inch diameter 250 ksi stress relieved strands. The beams were fabricated of both normal-weight and lightweight concrete and stored for a 300-day period. At the end of the storage period, the beams were installed in the 40 ft and 56 ft spans of a bridge on IH-610 over South Park Boulevard in Houston, Texas. The camber calculations are, therefore, strongly correlated with the particular beam type and structure to which they were calibrated.

Empirical Formulation

The calculation method developed by Sinno was fully implemented in *PSTRS11* and employs empirically based unit hyperbolic creep and shrinkage functions and a step-wise time-increment numerical procedure. This program was never used in bridge design production for predicting camber, so the source code was not incorporated into *PSTRS10* or *PSTRS14*. Instead, a very simplified single step method of calculating the camber at mid-span, using a single set of assumed creep and shrinkage values–unit shrinkage of 0.000325 (dimensionless) at infinite time and unit creep of 0.000000225 (in^2/lb) at infinite time–are included in *PSTRS14*. The justification for this simplification is the presumption that camber calculations are inherently inaccurate because of the multitude of contributing factors that are largely unknown at design time so there is no need to improve the prediction of what cannot be reliably predicted by the design engineer. The design engineer may not agree with this logic and may choose to employ other means to estimate beam camber. But in practice, *PSTRS14*'s calculated camber is assumed to be good enough by most bridge design engineers in spite of some field data to the contrary.

One known shortcoming of *PSTRS14*'s camber at deck placement estimation has been in the case of U-Beams. Early experience with U-Beams indicated that they consistently achieved only about 75% of their calculated camber. Therefore, the practice has been to use 75% of the *PSTRS14* camber when performing haunch calculations. That is an admission that *PSTRS14* has been overestimating the camber of U-Beams. This shortcoming was at least been partially addressed starting with *PSTRS14*, v5.1 which uses a more rigorous procedure for calculating the initial elastic camber of straight partially-bonded-strand beams (of which U beams are a subset), than was used in previous releases of the program (see *Improved Calculation of Elastic Camber Produced by* section for a detailed discussion of this "improved" procedure).

Improved Calculation of Elastic Camber Produced by Prestress Force

For all beam types, the old procedure for camber due to prestress is a summation of the camber contributions of:

(1) the end moment camber equation $\dfrac{M\ \ell^2}{8EI}$, where M = prestress force times eccentricity at the end of the beam, ℓ = beam length, E = modulus of elasticity of beam at release of prestress (a.k.a. transfer of prestress) and I = moment of inertia of beam; and

(2) the hold-down-force camber equation $\dfrac{b(3-4b^2)N\ell^3}{24EI}$, where $N=\dfrac{Pe'}{b\ell}$, P = prestress force, e' = difference in eccentricity between hold down point and beam end, b = fraction of ℓ between beam end and hold down point for the draped strand pattern, and ℓ, E and I are as previously defined.

In the case of partially-debonded-strand beams, such as U-Beams, the pseudo hold down points are the points between which all strands are fully bonded. As implemented in *PSTRS14* v5.0 and earlier, the hold down point camber equation (based on *P*, not *M*) with its pseudo hold down point tends to overestimate camber. This is because the pseudo hold down point is located farther and farther from the end of the beam as debonding progresses toward midspan and at the same time P is assumed constant throughout beam length, ℓ, even though it actually varies from a minimum value at beam end where debonded strands are most numerous to the maximum value between the two "hold down" points.

Starting with *PSTRS14* v5.1 the user has the option (through an entry on the SPEC card) of choosing a more statically correct camber formulation that explicitly takes into account the debonded length of each partially debonded strand for the case of debonded strand beams. This formulation uses as the equivalent loading on the beam a series of "end moments" starting at the ends of the beams for fully bonded strands and moving thru each "debonded to" location to the points either side of midspan where all strands are fully bonded. Each moment represents an increment of fully bonded strands that start on the interior side of a debond increment/distance (called a "layer" within *PSTRS14*) and ends at the corresponding location on the other end of the beam where the strands are again debonded. The formulation for a single strand or a single row of bonded strands is $\frac{M\ \ell^2}{8EI}\left(1-4b^2\right)$, where M = prestress force times eccentricity of the given row of bonded strands, ℓ, E and I are as previously defined, and b is the fraction of ℓ between beam end and the interior side of the layer for which the calculation is being performed. The first layer has zero length and thus captures the strands that are fully bonded throughout beam length, ℓ.

Implementation involves summing up the effects of each group of bonded strands on a row by row, layer by layer basis. This is all statically correct and follows the PCI Bridge Design Manual, Section 8.7, Camber and Deflection [13]. However, implementation in PSTRS14 v5.1 also involved some simplifications in the determination of prestress force for each group of strands. These simplifications make the calculated camber an upper bound solution, though not as high an upper bound as was the case in previous version of *PSTRS14*. Note that elastic effects are always followed by proportional inelastic (time dependent) effects due to creep of concrete.

Because of the strong correlation with the research data from the Type B beams of the bridge on IH-610 over South Park Boulevard in Houston, Texas, *PSTRS14*'s camber calculation method also may not provide an adequately accurate prediction of beam camber for design purposes when applied to other beam types (i.e. other volume-to-surface and span-to-depth ratios) than I-beams of the span-to-depth ratios investigated, other material constituents, other storage periods, other final location and framing plan, as well as other factors not considered in Sinno's method nor implemented in the original precursor program *PSTRS10*. Some of these factors and other factors described by Kelly, et al [14] significantly influence camber at erection. Therefore, under no circumstances should the calculated camber of *PSTRS14* be considered as having the same degree of certainty as, for example, the concrete strength required. The value output for camber at erection (assumed to be that immediately prior to placement of any portion of the deck, whether precast sub-deck panels or cast-in-place concrete) should therefore be considered a rough estimate only and is not applicable to all possible design options, beam types, aggregate types, etc.

The user should verify that the calculated camber versus the dead load deflection due to placement of all superimposed dead load results in a beam with a positive net camber, though the program does not calculate this residual camber as a design parameter (see the *Optional Life Cycle Camber* section for a way to estimate this). If the camber needs to be increased, the user may do so by adding additional strands using the analysis option. This would not, however, guarantee that the profile of the beam will always have a net positive camber throughout the service life of the bridge as the program does not calculate time depended deflection effects after deck placement, except when doing an *Optional Life Cycle Camber* analysis.

Notwithstanding the effects of sectional differences in area and moments of inertia, camber calculations performed by the program are thus somewhat insensitive to the beam type (except that starting with *PSTRS14* v5.1 the initial elastic camber of partially debonded strand beams may, at the user's option, be calculated more statically correct than was previously the case) and many other factors that affect the actual camber of prestressed concrete beams.

The v5.0 edition of this user guide included the following statement appended to the previous paragraph: "*Furthermore, final concrete strength alone is used to determine beam stiffness so the method is not affected by the initial concrete stiffness associated with f'_{ci}.*" This is an incorrect statement. Previous versions of *PSTRS14* as well as v5.1 and v6.1 do indeed use f'_{ci} in the calculation of initial elastic camber. See the *General Notes on Analysis Mode* for a situation where the noted statement is appropriate.

Whether employing the more statically correct calculation of elastic camber of partially bonded U-Beams, and the resulting change in the time dependent inelastic effects warrants a change in the "knock down" factor to be applied to U-beam camber when calculating beam haunch values is left up to the user to decide based on field experience and engineering judgment.

Optional Life Cycle Camber

Implemented in *PSTRS14* Version 6.0, for the user's information, is an option to generate a new report that uses the analytical technique developed by Kelly, et al [14] to estimate what is termed in PSTRS14 as Life Cycle Camber. The Life Cycle Camber Report (LCCR), rather than being a single design camber value, is a collection of elastic and inelastic camber values estimated for important events and time durations in the life of the beam. When plotted against their assumed time of occurrence they give an indication of the trends in beam camber over the life cycle of the beam (hence the name, "Life Cycle Camber"), including the residual camber that remains in the beam long term. If the camber values are plotted versus their associated time of occurrence, the resulting camber curve is similar to that produced by PGSuper.

The analytical technique reported in Reference [14] is a modification of the PCI multiplier method of estimating time dependent camber and deflections. The procedure was used to accurately predict the time depended response of four prestressed concrete bridge girders the researchers instrumented and monitored from release of prestress thru the early service life of the bridge. The researchers then used the empirically verified program to calculate the sensitivity of time dependent camber and deflection to key variables such as concrete strength, creep of concrete, and construction schedule. Based on the results of this sensitivity exercise, the research team estimated that camber of beams similar to those studied could vary from 2 to 6 inches at erection and end up with between -0.75 and 2 inches of residual camber at the end of service life. This potential variation should be kept in mind when using any calculated design camber and certainly when interpreting the LCCR (.cam file) generated by *PSTRS14* v6.1.

Unlike with traditional hand or spreadsheet calculations of beam haunch, no "fudge factors" are applied to the various camber and deflection components of Life Cycle Camber calculations to reduce a particular value of an elastic response or of the camber at erecting (as has typically been done for U-Beams). The current values for modulus of elasticity based on design release or final concrete strengths (i.e. those associated with the assumed age of the beam when each event is considered), or based on a user defined E_c versus time curve, is employed when calculating the elastic effects. The effects of loss of prestress are estimated by a hyperbolic curve based on the difference between initial and final losses calculated by the loss procedure selected by the user.

For these, and only these, calculations, the span length during storage is assumed to be the length of the beam between supporting dunnage and is equal to the beam length minus twice the user specified distance (input as a percent of beam length) from the end of the beam to the centerline of the dunnage (which defaults to 3% of the beam length, the maximum length allowed by the *TxDOT Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges* (2004 Edition) [16]). The actual variation in dunnage location alone could account for a lot of the variability seen in erection camber between otherwise identical beams, illustrating just one reason why prediction of beam camber is somewhat elusive (note that PSTRS14's design camber assumes that the beam is fabricated and stored with a span length that is equal to the center-to-center of bearing distance the beam will have after it is set in place on bridge bearings).

Data used by this new feature is provided in part by two optional input "cards" and in part by the data input for the current design or analysis or derived therefrom. Optional input card, 'LCCR' is required to invoke the Life-Cycle Camber calculations and may be used to provide user-defined input in place of defaults, including assumed beam age at various events. Optional input card, 'USGC', which if used must be flagged as such on the 'LCCR' card, may be used to define a concrete-strength-versus-time curve in place of the program's default concrete-strength-versus-time curve (derived from the programs design concrete strengths, or, in the case of the analysis mode, the user's input concrete strengths). This curve is determinative of the concrete-elastic-modulus-versus-time (E_c vs t) curve. Included also on the 'USGC' card is a field for entering a K_1 factor to be applied to E_c , thus E_c (mod) = $K_1 * E_c$, to allow adjustment of elastic modulus due to aggregate type, or for any other reason, should a user want to consider a softer or harder aggregate type / concrete in an optional design or investigation.

Life-Cycle Camber output consists of a separate report (filename ending in '.cam'), which includes:

1. Re-iteration of pertinent input data, including timing of major events;
2. Estimated elastic cambers and deflections before and after each event; and
3. Time-dependent camber changes associated with each event.

Composite Slab Width

For standard beams, an entry for the composite slab width on the BEAM card overrides the values calculated in accordance with the AASHTO Specifications, which, in the case of effective slab width starting with LRFD 09 is equal to the beam spacing.

For a non-standard beam, an entry is required if a slab thickness or CPR1 with haunch is entered. The composite slab width is used in the calculation of slab cross section properties for both serviceability and ultimate (strength) conditions.

Since *PSTRS14* does not have an input for skewed conditions and therefore cannot check the limitations of the specification, it is up to the user to make sure the maximum skew angle at the bridge being designed or analyzed is not outside the boundaries of the LRFD 09 provisions (i.e.

75 degrees) when calculating the composite slab width. If the skew angle is greater than this limit the user may enter the appropriate value of the slab effective flange width as determined by a refined analysis which would need to be conducted outside of *PSTRS14*.

The composite/effective slab width is set to the beam spacing for dead load calculations.

Concrete Strength

The required final concrete strength is typically controlled by compressive stresses, either in the top of the beam at or near mid-span, or at the bottom of the beam at or near the ends. It may also be controlled by bottom fiber tension, release concrete strength or flexural capacity ("ultimate moment") requirements. The required release strength is often controlled by the stress at hold-down locations or at the end of the beam for draped-strand beams, and at the mid-span, ends, or debonding locations for straight-strand beams with or without debonding. The minimum release concrete strength is set at 4000 psi, or the value entered by the user on the MAT1 card, and minimum final concrete strength is set at 5000 psi, except as modified by the user input of the minimum concrete strength gain between release and final on the MAT1 card.

Deflections

Instantaneous elastic deflections are shown for dead loads due to slab, shear key, overlay, composite regions of non-standard beams and "other" (which includes the standard I beam interior diaphragm and the entered non-composite and composite uniform and concentrated dead loads). A total of all deflections is also given.

Beginning with *PSTRS14* v 5.2 dead load deflections are segregated between non-composite and composite deflections so that the user can more readily determine how much deflection results from each portion of the total non-composite and composite loads. Note that it is customary (i.e. TxDOT practice) to report in contract plans the deflections of the beam in service based on an assumed value of modulus of elasticity of 5,000,000 psi (5000 ksi) for slab and beam concrete and for this reason the modulus of the beam is customarily set equal to that of the cast in place slab, with both input as 5,000 ksi, rather than letting the modulus float with required beam release and final concrete strengths and with assumed slab strength.

The modulus of elasticity (E_c) of the beam used in the deflection calculations will be the E_c entered on the MAT1 card (entered in ksi units). If no value is entered, the E_c of the beam will be calculated by the following equation, which will be converted to ksi units for internal calculations:

$$E_c = w_c^{1.5} \cdot 33 \cdot \sqrt{f'_c}$$ *AASHTO Standard Specifications* 8.7.1 (33 = 0.043 for metric units)

This equation, which uses w_c (unit weight of the concrete) in pcf and f'_c in psi, yields E_c in psi units and corresponds to LRFD 6th Edition Equation 5.4.2.4-1, which uses w_c in kcf, f'_c in ksi, and a coefficient of 33,0000 to yield E_c in ksi units.

Diaphragms

Diaphragm loads for standard U beams are automatically included when designing a standard U beam. The internal diaphragms are placed 10 feet from the centerline on both sides of the beam. For a U40 beam the diaphragm weight is 2 kip and for a U54 it is 3 kip. If the number of concentrated loads on the non-composite section input on the LOAD and LOCL cards exceeds 12 (a maximum of 14 is allowed), the diaphragms will not be included. Also, U beams less than 4 feet (which is a practical impossibility) are assumed not to have diaphragms. Note that diaphragm weights are included as non-composite concentrated loads applied at the same time beam weight is applied (i.e. at time of release of prestress).

For TxDOT Standard I-Beams, the number of diaphragms may be entered in col. 60 of the BEAM card. However, if a number is entered in col. 60 of the BEAM card for any other beam type, it will be ignored. These diaphragms are assumed placed after the beam is erected. TxDOT's current practice is to not use such diaphragms.

Diaphragms for all other standard beams and for non-standard beams may be specified using the LOAD/LOCL cards, entering the diaphragms as concentrated dead loads on the non-composite section.

Haunch

The beam haunch is a concrete pedestal between the slab and the beams that is used to ensure that the profile of the beam does not encroach into the specified minimum slab thickness.

Factors affecting the required haunch include beam camber at the time of slab placement, non-composite dead load deflection, roadway cross-slopes, super-elevation transitions, roadway vertical curves and top flange width. These factors have a significant effect for girders which are placed to follow the roadway cross-slope (i.e. Box beams, Double-T beams, U beams and Slab beams), including the effect of the negotiated girder cross-slope.

If a haunch is to be included as part of the composite section, the haunch width and depth at the centerline are entered on the OPTL card. The haunch will then be included as part of the slab and composite section. Due to uncertainty in the realized depth of haunch at the centerline of the beam, inclusion of the haunch as part of the composite section is not advised.

The minimum haunch depth is a calculated value based on a camber that can only be crudely estimated and the haunch depth at the critical design section could be considerably less than the entered value. Therefore, the calculated composite section could be larger than the actual composite section. Another disadvantage to including the haunch as part of the composite section is that the haunch depth at the centerline would be entered and used for all locations along the span for stress calculations even though the haunch depth is not constant along the span.

A preferable way of including the haunch in the design process is to enter its dead load on the SPEC card as an equivalent uniform dead load on a non-composite section. In this way, the dead load of the haunch is included in the design, but the haunch is not included as part of the composite section. A realistic way to include the dead load of the haunch is to calculate an equivalent haunch depth assuming that the force of interest is the moment on the non-composite beam at midspan. It can be shown that the formula below calculates such an equivalent load.

$$= w_c \times w_f \left[\frac{1}{6}(X - t_S) + \frac{5}{6}(Z - t_S) \right]$$

where:

w_c = density of concrete (i.e. 150 lb/ft^3 (23.6 kN/m^3))

t_s = thickness of slab

Notes:

(1) This is a uniform load that when applied to the beam would cause the same moment at midspan as the assumed parabolic haunch.

(2) See Non-Standard (User Defined) Beam Cross Sections for a discussion of haunch entries for nonstandard beams.

Live Load

AASHTO

Allowable entries for AASHTO design trucks are H15, H20, HS20, and HL93. HS20 is the default live load for Standard specifications designs and HL93 for LRFD designs.

For Standard specifications, the HS20 truck load controls for span lengths to 144.8 feet; the lane load controls thereafter. From 33.8 feet to 144.8 feet, when all three axles are on the span, the maximum live load moment occurs at 2.33 feet from mid-span. Since *PSTRS14* uses the mid-span as the critical location, the program places this maximum moment at the mid-span for all mid-span calculations. For span lengths between 10.9 feet and 37.1 feet, the minimum load controls over the truck load. This minimum load is a tandem truck with two 24 kip axles spaced 4.0 ft apart (25 kip for HL93). Control due to this alternate load is determined automatically in the program when the default live load, HS20 or HL93, is used.

The overload provisions of AASHTO have not been incorporated into *PSTRS14*.

AREMA

Railroad live load may be entered on the SPEC card. These loads are given as ratios and can range from E50 through E150.

Non-Standard Live Load

A non-standard live load can be specified by LVEC/LOCL and LVEU/LOCL cards. Since the magnitudes and axle spacing of such non-standard loadings are by definition non-standard the standard absolute maximum moment location of 2.33 ft from mid-span cannot be relied upon. Therefore the calculation of absolute maximum moment is not captured and assigned to midspan as it is for the standard live load. The truck load moments at the 10th points and other point of interest are, however maximized.

Live Load Distribution Factor

For *AASHTO Standard Specifications* the default live load distribution factor is *S*/11 (axle load) for standard I-beams and TxGirders, where *S* is the beam spacing. The user must determine and enter live load distribution factors for standard Box beams, U beams, Double-T beams, Slab beams, Decked Slab beams, X beams and non-standard beams.

For LRFD specifications input of moment and shear live load distribution factors is required for all beams. The moment distribution factor is input on the BEAM card and the shear distribution factor is input on the LLDF card.

For AREMA loading, the default *S*/11 for standard I-beams and TxGirders should be overridden with a LLDF entry based on the specific parameters for the design.

For designs having no live load, enter ".0001" for the live load distribution factor, so that the default live load effects will be "zeroed out".

Messages

When an analysis determines that a design is deficient, "BEAM DOES NOT SATISFY DESIGN REQUIREMENTS" is printed on the output. This note is not to be ignored. The messages under this heading must be reviewed in detail and appropriate action taken if required. The decision to display this message is, however, based on mathematical exceedances with no programmed percent exceedance allowed (such as a rational judgment that a few psi overstress as close enough); therefore, the user should consider the relative differences between the values (e.g. how much an allowable is exceeded) to determine whether a deficiency is significant and warrants remedial action.

Messages under "NOTES" but before "BEAM DOES NOT SATISFY DESIGN REQUIREMENTS" are, in general, for the user's information only. An example is "INITIAL TENSILE STRESS EXCEEDS 3 * SQRT(F'CI) OR 200 PSI." Historically, few problems have occurred in Texas that could be attributed to this tension, even when bonded passive reinforcement is not specifically sized per the code to accommodate it. The user must use sound engineering judgment to determine whether this note can be ignored or whether the stress is sufficiently high to require the calculation of the resistance provided by the bonded reinforcement in the top flange. If calculation is indicated, the resistance should be determined in accordance with *AASHTO Standard Specifications* 9.15.2.1 or *LRFD Bridge Design Specifications* 5.9.4.1.2. Another note, "END FINAL COMPRESSION EXTREME, BUT NOT ALLOWED TO CONTROL," tells the user that the calculated end final compressive stress exceeds the stress limit, $0.4f'_c$ for Standard specifications, and $0.45f'_c$ for LRFD. See discussion under the previous section, *Allowable Stresses*.

Two out-of-bounds messages, preceded by "CAUTION," may appear on the first page of the output. If the slab thickness entered on the BEAM card is less than 5 inches or greater than 20 inches, a "SLAB THICKNESS OUT OF BOUNDS . . . " message is printed for standard I, TxGirder and non-standard sections. This message is not printed for standard Box beams, Double-T beams, U beams, Slab beams, Decked Slab beams, and X beams because they either can be constructed without a slab or the construction of a slab less than 5 inches is not physically possible. If the live load distribution factor entered on the BEAM card is less than 0.100 or greater than 2.00, the "LIVE LOAD DISTRIBUTION FACTOR OUT OF BOUNDS . . . " message is printed. These out-of-bounds messages are to alert the user of possible input error; however, the program continues the beam design using these entered values, which may very well have been intended by the user.

For LRFD specifications, the message "SHEAR LONGITUDINAL REINFORCEMENT CHECK REQUIRED THE ADDITION OF NN STRANDS" (where NN is a number) will be printed out if additional strands have been added by the program to satisfy the minimum bonded longitudinal reinforcement for shear check. When doing an analysis, the message “FAILED LONGITUDINAL REINFORCEMENT CHECK FOR SHEAR” will be printed out under “DESIGN DEFICIENCIES” when required shear reinforcement exceeds the maximum that can be provided (i.e. minimum spacing allowed) in order to meet the longitudinal reinforcement requirement.

The messages discussed above do not constitute all possible messages that the user may encounter when running *PSTRS14*. Rather, they serve as examples of the types of messages produced by the program to alert the user to possible problems with the beam design or otherwise just for the user’s information.

Pedestrian Bridge

Pedestrian live load is not a standard live load in *PSTRS14*, but it can be entered as a non-standard uniform live load on the LVEU/LOCL cards. In this case, the length of the load would be the center-to-center bearing length of the beam. The load magnitude would be changed slightly from the applied pedestrian load. The pedestrian load is typically expressed in pounds per square foot, where the input uniform live load must be in kips per foot. The per square foot pedestrian load must be multiplied by the beam spacing in order to determine the load per foot. Additionally, the program multiplies this uniform live load by the live load distribution factor, but the pedestrian load should not include this factor. The live load distribution factor(s) should therefore be set to 1.0, so as to use the full pedestrian live load input by the user.

Camber versus dead load deflections should also be checked for pedestrian bridges. It is possible that the small number of strands required for the loading may not result in adequate camber to overcome the dead load deflections. Also, even if starting out with positive camber a beam that has a small camber may very well sag over time. Generating a Life Cycle Camber Report will give the user some idea of whether sagging might occur.

Prestress Losses

The user may select from among four distinct prestress losses specifications/methodologies, depending on whether the *AASHTO Standard Specifications* for Highway Bridges or *AASHTO LRFD Bridge Design Specifications* are chosen as the design specifications. Of the three prestress losses methodologies available for use with the LRFD Specifications, the third method is derived from a TxDOT research project’s recommended modifications to the AASHTO LRFD Bridge Design Specifications, which have not been adopted by AASHTO and if adopted may not be adopted exactly as these are coded in *PSTRS14*.

For LRFD designs, prestress losses are based on provisions of AASHTO LRFD 3rd Edition (2004), AASHTO LRFD 4th Edition (2007) or the TxDOT 2012 procedure, with the 2004 methodology being the default. Due to concerns that the 2007 AASHTO LRFD losses were unconservative, TxDOT adopted a design policy which directed bridge engineers to use the 2004 AASHTO LRFD losses for TxDOT projects until research on the effects of adopting the new losses could be completed. [8] The TxDOT 2012 (Project 0-6274) losses were the outcome of that research. [7] Note that the TxDOT 2012 losses in *PSTRS14* should not be confused with the prestress loss provisions of the AASHTO LRFD 6th Edition (2012) specifications, which are the same as those of the AASHTO LRFD 4th Edition (2007) specifications.

See the Bridge Design Manual - LRFD [8] for current TxDOT policy regarding calculation of prestress losses for prestressed beam analysis and design.

Standard Spec Losses Method

For Standard Spec designs, only the AASHTO 1994 Spec losses (applicable to all Standard Specs thru the 17th Edition, 2002), or lump sum losses, may be used.

LRFD Spec Losses Methods

If LRFD Spec design is chosen, the user may specify either the 2004 or 2007 AASHTO LRFD Spec losses or the TxDOT 2012 Losses, regardless of the LRFD Spec chosen for design. If 2004 Spec losses are selected, the user may, as with the Standard Spec losses, override the calculated values by entering lump sum initial and final losses, but lump sum losses cannot be specified if 2007 AASHTO LRFD Losses or TxDOT 2012 Losses are the user's selected loss procedures.

TxDOT 2012 Losses Method

In September 2009 TxDOT launched Research Project 0-6374, *Effects of New Prestress Loss Predictions on TxDOT Bridges*. The draft report's recommended losses (termed TxDOT 2012 Losses, herein) are presented in this section in the form they have been implemented in *PSTRS14*. The other losses methods are published in the various AASHTO LRFD specifications and so are not detailed in this user guide.

R1, Strand Relaxation at Transfer (modification of AASHTO LRFD 2007 thru 2012 Equation C5.9.5.4.2c-1):

$$\Delta f_{pR1} = \frac{\log(24.0t)}{K_L^{'}}\left[\frac{f_{pj}}{f_{py}} - 0.55\right] f_{pj}$$

where,

t = time estimated in days from stressing to transfer (days). The unit for input of t in *PSTRS14* is hours rather than days, with the software making the needed conversion in the loss formula.

f_{pj} = initial stress in the tendon at the end of stressing, i.e. after transfer of the prestress force (ksi).

f_{py} = specified yield strength of prestressing steel (ksi).

$K_L^{'}$ = 45 for low relaxation steel, 10 for stress relieved steel.

This equation is used in TxDOT 2012 and in the AASHTO LRFD 2007 Losses methods as they are implemented in *PSTRS14*.

ES, Elastic Shortening at Transfer (modification of AASHTO LRFD 2007 thru 2012 Article 5.9.5.2.3):

$$\Delta f_{pES} = \frac{E_p}{E_{ci}} f_{cgp}$$

where,

E_p = modulus of elasticity of prestressing steel (ksi).

E_{ci} = modulus of elasticity of concrete at transfer or time of load application (ksi).

f_{cgp} = the concrete stress at the center of gravity of prestressing tendons due to the prestressing force immediately after transfer and the self-weight of the member (ksi).

For determining the initial stress in the strands immediately after transfer of the prestress force, Research Report 0-6374-2 recommends that the prestressing steel be assumed stressed to $0.7f_{pu}$ to avoid consideration of initial losses which would require iteration. That way all loss calculations could be performed independently, promoting "hand" solutions. *PSTRS14* determines the initial prestress by considering the loss due to relaxation between jacking and transfer and the loss due to elastic shortening, thus utilizing an iterative procedure to determine the prestressing force immediately after transfer, a method that was already established in the program logic of prior versions.

The change in prestressing steel stress due to elastic deformations of the section may be determined for any applied load. This is used in the AASHTO LRFD 2007 Losses method to calculate elastic gains due to deck placement. In the TxDOT 2012 Losses method, such elastic gains are explicitly excluded from the calculated prestress losses; however, the stresses due superimposed loads are included in creep calculations and do result in lower creep losses.

SR, Shrinkage of Girder Concrete (modification of AASHTO LRFD 2007 thru 2012 Equation 5.9.5.4.2a-1):

$$\Delta f_{pSR} = E_p \left(\frac{140 - H}{4.8 + f'_{ci}} \right) 4.4 * 10^{-5}$$

where,
E_p = modulus of elasticity of prestressing steel (ksi).
f'_{ci} = specified concrete compressive strength at transfer (ksi).
H = relative humidity (%).

CR, Creep of Girder Concrete (modification of AASHTO LRFD 2007 thru 2012 Equation 5.9.5.4.2b-1):

$$\Delta f_{pCR} = 0.1 \left(\frac{195 - H}{4.8 + f'_{ci}} \right) \left(\frac{E_p}{E_{ci}} \right) \left(f_{cgp} + 0.6 \Delta f_{cdp} \right)$$

where,
Δf_{cdp} = change in concrete stress at the center of gravity of prestressing steel due to permanent loads, with the exception of the load acting at the time the prestressing force is applied.
f_{cgp} = the concrete stress at the center of gravity of prestressing tendons due to the prestressing force immediately after transfer and the self-weight of the member (ksi). See comment on initial prestressing stress, above in the *ES, Elastic Shortening at Transfer…* section.
E_p = modulus of elasticity of prestressing steel (ksi).
E_{ci} = modulus of elasticity of concrete at transfer (ksi).
f'_{ci} = specified concrete compressive strength at transfer (ksi).
H = relative humidity (%).

For simply supported members permanent loads will produce tension at the center of gravity of the prestressing steel, making Δf_{cdp} a negative value which reduces calculated CR. This creep "gain" is similar to that implicit in the AASHTO LRFD 2004 Losses creep loss equation. But, as noted above (in the ES section), explicitly calculated elastic gains are not components of prestress losses in either the AASHTO LRFD 2004 or TxDOT 2012 methods, but the elastic gain due to deck placement is a component of the AASHTO LRFD 2007 (thru 2012) loss methodology.

R2: Relaxation of strands after transfer (modification of AASHTO LRFD 2012 Equation 5.9.5.4.2c-1):

$$\Delta f_{pR} = \frac{2 f_{pt}}{K_L}\left(\frac{f_{pt}}{f_{py}} - 0.55\right)$$

f_{pt} = stress in prestressing strands immediately after transfer (ksi). See comment on initial prestressing stress, above in the *ES, Elastic Shortening at Transfer…* section.
f_{py} = specified yield strength of prestressing steel (ksi).
K_L= 30 for low-relaxation strands and 7 for other prestressing steel, unless more accurate manufacturer's data are available.

Equation 5.8.5.4.2c-1 does not consider the relaxation reducing effects of creep and shrinkage. The more complicated equation shown in the Commentary (C5.9.5.4.2c-1) is used in the PSTRS14 implementation of AASHTO LRFD 2007 losses. In recognition of the apparent overly conservative results when not considering creep and shrinkage effects in long term relaxation calculations, AASHTO states that "The relaxation loss…may be assumed equal to 1.2 ksi for low relaxation strands" which means basically that there is an allowable upper limit on Equation 5.8.5.4.2c-1. When applied to the modified equation above, this allowable limit becomes 2.4 ksi. This limit is applied in the TxDOT 2012 Losses (**Note:** Research Report 0-6374-2 proposes limiting relaxation loss to 2.4 ksi).

More About Losses Methods

For AASHTO 1994 losses, the initial prestress loss is assumed to be the initial elastic shortening loss plus one-half the prestressing steel relaxation losses. For AASHTO LRFD 2004, 2007, and TxDOT 2012 losses, the initial prestress loss is assumed to be the initial elastic shortening loss plus the relaxation losses occurring during the time between jacking and release. The assumed time from jacking to release can be input on the SPEC card and defaults to 24 hours.

For Standard Spec designs, the prestress loss calculation procedure is similar but not identical to that of the 2004 AASHTO LRFD specifications. In particular, the initial relaxation loss for Standard Spec design is assumed to be one half of the total relaxation loss and this initial loss is not added into the final total losses, whereas for the *2004 AASHTO LRFD Bridge Design Specifications*, which uses a similar total relaxation loss equation, the initial loss is calculated by a formula similar to that presented in ***TxDOT 2012 Losses Method*** and added to the total losses as a separate relaxation component.

The TxDOT 2012 procedure uses the same overall methodology of the 2004 AASHTO LRFD specifications but with different formulations of some loss components.

Each time the prestress loss subroutine is called, the subroutine iterates calculations until the initial prestress loss converges to within 0.01%.

An option to enter the prestress loss percentages is available on the SPEC card (for Standard Spec and 2004 AASHTO LRFD specified losses, only) should the user wish to calculate losses using alternate methods or otherwise specify lump sum losses.

Prestressing Strands

Strand Type

Beams having either low-relaxation seven-wire strands or stress-relieved seven-wire strands may be designed or analyzed; Low-relaxation strand is the default.

Table 1 in **Error! Reference source not found. Appendix A – Table 1 and Figure 1 thru Figure 19 Error! Reference source not found.**lists the standard strand sizes available in *PSTRS14*. Only "Seven-Wire" strands conforming to ASTM A416 are listed. The "special" (SP) strand type is that conforming to ASTM A416, strand designation 13a.

A detailed description of the input options for strand size, type, area and strength follows the input instructions of the command STRD – Prestressing Strands.**Error! Reference source not found.**

Placement of Strands

Typical grids for the placement of prestressing strands are shown for each of the standard beam types. The standard practice for strand placement is to place them as low as possible in the grid, filling up each row completely with strands before proceeding to place strands in the next higher row. However, in certain circumstances a modified strand pattern is determined by the design algorithm as discussed below in the *Strand Pattern Modification* section. If in the design of a standard section a change in the strand grid is needed, the MSPR/LOCR cards can be used to modify the strand grid, while maintaining the beam as a standard section. For Example, to limit the release stresses in TxGirders when using 0.600" strands, it may be prudent to modify the maximum number of strands in some rows near the bottom of the beam. The MSPR/LOCR cards are required to define such a non-standard strand grid of an otherwise standard beam section. This does not make the beam a non-standard section but does require that a non-standard strand pattern be so indicated on the contract plans as explained in the *Strand Pattern Modification* section.

Number of Strands

The number of prestressing strands is dependent, in part, upon the algebraic sum of the allowable tension in the concrete and the bottom fiber stress at mid-span due to all loads. When performing a design a trial number of prestressing strands is determined based on the magnitude of these stresses, assuming that the mid-span eccentricity is equal to the distance from the centroid of the beam to the bottom fiber. The number of strands is increased in increments of two to obtain extreme fiber stresses within the allowable values, with six strands being the minimum number allowed.

The program logic is such that in design mode the final bottom fiber stress at mid-span due to service loads is explicitly handled by the chosen strand pattern, with due consideration of the allowable tensile stress. Final top fiber compressive stresses at mid-span may control the required final concrete strength, which would then be used to set the allowable tensile stress and therefore the designed strand pattern at mid-span. For AASHTO 2007 and TxDOT 2012 losses methods the total calculated prestress loss varies along the beam and thus points other than midspan may control the strand pattern required.

The number of strands may also be set by flexural capacity requirements or, in rare cases, by the longitudinal force requirements of the shear provisions of AASHTO LRFD.

Strand Pattern

All beams have either a draped strand pattern, a straight fully bonded strand pattern or a straight partially debonded strand pattern. The default pattern for standard I, TxGirder and Double-T beams is a draped strand pattern. A partially debonded strand pattern is the default for standard Box beams, U beams, Slab beams, Decked Slab beams and X beams. However, the defaults for strand pattern types can be overridden. For example, a straight (fully bonded or partially debonded) strand pattern for an I-beam/girder could be designed. However, unlike *PGSuper* Release 3.0 and descendants, *PSTRS14* does not do a draped strand design, a straight fully bonded and a straight partially unbounded design and the pick the optimum design solution.

To obtain the straight strand pattern with debonding allowed in a standard I, TxGirder, Double-T or non-standard beam enter "WD" (With Debonding) on the STRD card. To obtain the straight strand pattern with no debonding allowed in any beam enter "ALL" and "ND" (No Debonding) on the STRD card.

Strand Pattern Modification

A modification to the strand pattern is made to reduce excessive initial or final tension stresses at the hold-down locations. Strands are moved from a lower to a higher row, thus reducing the eccentricity and the extreme fiber stresses due to prestress. The resulting non-standard strand pattern will have partially filled strand locations at mid-span with strands placed in a higher row or rows. When this occurs, an asterisk is printed between the Beam Type and Total Number of Strands columns of the beam summary and CAD output file to alert the user and the non-standard strand pattern is explicitly indicated in the CAD output file.

Draped Strands

For standard I, standard TxGirder and non-standard beams with harped (a.k.a. draped) strands, all harped strands in a row (default=2) are placed first, with increments of two straight strands added thereafter to fill a row.

For standard Double-T beams with draped strands, strands are placed in increments of four, with the bottom row remaining straight. For standard Double-HT beams, strands are placed in increments of four, beginning with the center strands of each stem. The outside strands of each stem in the bottom row must remain straight (not draped).

The required end eccentricity is dependent on the initial top and bottom fiber stresses at the ends of the beam. All harped strands are raised incrementally as a unit, until the stresses are within the allowable values or until the centroid of the top row of strands is two inches from the top of the beam (the maximum height of a strand row). If strands are placed at the topmost position and stresses are still excessive, the concrete release strength is increased with its recalculation based on the controlling end stress, or stress at the end of the transfer length when prestress transfer length is considered.

The default for the strand hold-down location is the greater of five feet or *L*/20 feet from mid-span.

Debonded Strands

Debonding of two strands at a time is done at uniform increments–called layers in the program logic–along the span, beginning at the end of the beam (the default increment is 3 ft). At each location debonding begins at the bottom row and moves up as needed. This sequence makes the most efficient use of debonding due to the greater eccentricities in the lower rows. The end eccentricity shown in the output for straight debonded strand beams is the eccentricity of the remaining bonded strands.

Debonding will continue until initial stresses are within the allowable limits or until a debonding limit is reached. Limits to debonding include the maximum percentage of debonded strands per row, the maximum percentage of debonded strands per section, the maximum debonded length per strand and the minimum number of bonded strands in the bottom row. When a debonding limit is reached, the initial concrete strength is increased and the design cycles until convergence. In some cases, the limits may prevent debonding, resulting in a straight strand pattern with no debonding.

The default maximum debonded length is set as the minimum of:

- 15.0 ft
- 0.2 x Span Length
- 10 x Debonding Increment
- 1/2 Span Length – Development Length

The user may override these defaults by inputting a value on the STRD card, but the input value may not be greater than 1/2 Span Length minus Development Length, nor than 10 times Debonding Increment. If the input value is greater than either of these, it will be set to the smaller of the two.

When the user inputs a set value for the allowable initial tensile stress and this limit cannot be satisfied by debonding, *PSTRS14* will continue debonding and use the default allowable tensile stress multiplier to determine the required initial concrete strength. A message will be output in this case stating "Tension at End exceeds input allowable tension. Required concrete strength based on default allowable tensile stress multiplier."

End Distance, Transfer Length, and Beam Length Considerations

In *PSTRS14* v6.1, the user has the option of considering the length over which prestress is transferred to the beam and the resulting effects this has on the beam design/analysis. When transfer length is used, full beam physical length is assumed at release of prestress, and bearing-to-bearing length is assumed thereafter. See the Optional Life Cycle Camber enhancement for an exception to the beam length for the storage time step (not a stress checked design/analysis stage). A previously unused field on the 'OPTL' card is now used to indicate how to incorporate transfer length in the calculations, as follows:

(a) Program defaults to no consideration of transfer length; or

(b) Transfer length is set equal to the number of strand diameters specified in the default AASHTO provisions or in the design specification indicated on the 'SPEC' card; or

(c) Transfer length is set equal to a user specified number of strand diameters.

When transfer length is considered, the final compressive concrete stress near the end of the beam is allowed to control f'_c when previously that point had been ignored in design calculations. If the user chooses not to consider transfer length effects, the program will revert to ignoring this point as it always did prior to *PSTRS14* v6.1.

Transfer length had previously been accounted for only in the check of the longitudinal force requirement of the shear calculations by linearly increasing the prestress force from zero at the beam end to the full prestress at 50 strand diameters (60 strand diameters for LRFD). For this calculation, prior to v6.1, and for the case where the v6.1 user does not explicitly consider prestress transfer, the centerline of the bearing is assumed to be 6.5 inches from the end of the beam, regardless of beam type. In v6.1 the appropriate value of beam end distance for the beam section being designed or analyzed (or the value input by the user) is used. The transfer length is also taken into account at each of the debonding locations of debonded strand beams.

Prior to v6.1, the transfer length was ignored in flexural calculations, except as it is used to appropriately determine development length.

Shear

The program calculates and reports the maximum required spacing of default or user specified size and yield strength of shear reinforcement to satisfy the provisions of the specifications. It is up to the user to verify that the beam's stirrup spacing is adequate by comparing it with the spacing calculated by the program, making sure that the provided spacing does not exceed the maximum require spacing at each section along the beam.

PSTRS14 does not determine size and configuration of additional reinforcement such as bursting reinforcement that is required in the end regions nor does it determine the stirrup spacing required for interface shear.

Methodology Used to Determine the Maximum Required Stirrup Spacing

Standard Specifications

Considering that the reaction to applied loads causes compression in the end region of a simply-supported pretensioned beam, if H is the depth of the composite section, then the shear strength provided to the beam by the concrete and the web reinforcement is calculated beginning at H/2 from the end of the beam for designs using the Standard Specifications with the shear stirrup spacing being constant from the end of the beam to H/2.

For shear design using the Standard Specifications as the primary specification, if the web reinforcement limit of $8\sqrt{f'_c}\, b_w d$ is exceeded, a message "WARNING: SHEAR CAPACITY IS

EXCEEDED” is printed in the output under “NOTES”. Asterisks are printed under “STIRRUP SPACING” at the locations where the shear capacity is exceeded. The design continues, but the user must revise the input parameters so that this limit is not exceeded.

LRFD Specifications

The shear strength provided to the beam by the concrete and the web reinforcement is calculated beginning at the critical section for shear design using the LRFD specifications (LRFD 5.8.3.2). The shear stirrup spacing is constant from the end of the beam to the critical section, for the LRFD specifications.

For shear design using the LRFD specifications, *PSTRS14* checks longitudinal reinforcement according to section 5.8.3.5:

AASHTO 5.8.3.5-1:
1. (Draped) No check between two hold-down points.
2. (Debonded) No check between points where strands become fully bonded.

AASHTO 5.8.3.5-2:
Check between beam end and critical point for shear.

Where these requirements cannot be met by reducing the spacing of the shear reinforcement, additional strands will be added. A letter “L” next to the spacing in the output denotes if the spacing is controlled by the longitudinal reinforcement requirement. This is a very rare occurrence.

Per LRFD 5.8.3.3, for LRFD compliant shear design the upper limit on the nominal shear capacity of $V_c + V_s + V_p$ for locations along the beam between the critical points for shear near the two ends of the beam is $0.25f'_c b_v d_v$,with $0.25f'_c$ being the maximum nominal shear stress on the concrete at capacity. For locations between the critical points and the beam ends the coefficient of this nominal shear stress is lowered to 0.18 to guard against “diagonal compression or horizontal shear failure along the interface between the web and the lower flange of the beam.” “Usually, the inclusion of additional transverse reinforcement cannot prevent this type of failure and either the section size must be increased or the end of the beam designed using a strut-and-tie model.” (LRFD C5.8.3.3) One solution that avoids having to develop a strut-and-tie model is simply to bump up final concrete strength, f'_c. This can be facilitated using the minimum strength gain between f'_{ci} and f'_c function first incorporated in *PSTRS14* v4.1 via the MAT1 card.

This 0.18 lower limit on nominal shear stress is implemented in *PSTRS14* beginning with v5.0 as follows (since *PSTRS14* utilizes symmetry and performs calculations and output from beam end to centerline, a singular critical point and beam end are discussed below):

(1) Between the critical point and beam end the default coefficient for “nominal shear stress on the concrete at capacity,” hereafter called “coefficient for nominal shear resistance” (CNSR), is 0.18. However, the user may override this with any coefficient up to the “between critical points” limit of 0.25, which is the value used for all calculation points in *PSTRS14* v4.2. If the user overrides the 0.18 coefficient with a higher value (not to exceed 0.25), the following message will be output:

Warning: End-region shear coefficient > 0.18
Strut & Tie Model required to justify input shear coefficient value.

If the user enters a value greater than 0.25 the program resets the coefficient to the default value of 0.18.

(2) The spacing calculated at the critical point for shear is used for the design points from that location to the beam end. Therefore, if a spacing is calculated at the critical point but "***" is output for one or more points between the critical point and the beam end, inclusive, the spacing for those points may be assumed to be the spacing calculated for the critical point. Whether or not to deem acceptable the excessive shear stresses at the points with "***" shown in the output is left up to the engineering judgment of the user but should not violate TxDOT design policy.

(3) If "***" is output at the critical point, the following message will also be output,

*** BEAM DOES NOT SATISFY DESIGN REQUIREMENTS ***
Shear capacity is exceeded (Vu/phi > (CNSR or 0.25)*f'c*bv*dv+Vp)

where, CNSR is the current value of the coefficient for nominal shear resistance for points between the critical point for shear and beam end, inclusive. The user is advised to heed this message, modifying the CNSR and taking appropriate measures to address the AASHTO LRFD Specification provisions or modifying a major bridge configuration parameters (e.g. beam spacing, span length, superimposed load, beam type, etc) so as to get a beam design that meets all design requirements.

Implemented beginning with v6.1 is the TxDOT's **Bridge Design Manual - LRFD** policy which directs bridge designers not to use the tabular values of beta (β) and theta (θ) for shear design as had been used in previous versions of PSTRS14, but rather to use AASHTO LRFD Equations 5.8.3.4.2-1 and 5.8.3.4.2-3, respectively.

Summary Output Files

Beam Summary

The Beam Summary output file (.sum) lists the design requirements for each problem and beam in the order of entry. An asterisk under "Non-Std Pat" indicates a design with a non-standard strand pattern. Camber, strand type (LR or SR) and dead load deflections are shown in this file; the debonded strand pattern is shown elsewhere.

Computer-Aided Drafting (CAD) Text Import Files

Two CAD text import files are produced, one for beams with no debonded strands (.smd) and one for beams with debonded strands (.sms). An asterisk in the fourth data field (column twenty-one of the text file) indicates a design with a non-standard strand pattern. The debonded strand pattern by row is shown in the CAD file after the shear live load distribution factor data field.

The text in the CAD text import files is arranged for importing into the various beam Non-standard span standards graphics sheets. However, some manual reformatting by the user may be required.

Transformed Sections

Transformed Concrete

In *PSTRS10*, the concrete modular ratio n was set to "1.0". In contrast, *PSTRS14* allows the option of using the theoretical n, which is the default value. (The theoretical n is the E_c of the slab divided by the E_c of the beam, where the E_c values are calculated according to *AASHTO Standard Specifications* Article 8.7.1 / LRFD Equation 5.4.2.4-1). Or the user may enter the E_c of the beam, E_c of the slab, E_c of the key, etc., on the MAT1 and MAT2 cards.

Historically, TxDOT policy has been to use 5000 ksi for both beam and slab concrete modulus of elasticity, E_c, for values of beam f'_c less than 7500 psi. This has resulted in the practice of using a modular ratio of 1.0.

The user may note a slight difference between the E_c of the beam printed under "CROSS SECTION AND MATERIAL PROPERTIES," and the E_c of the beam calculated based on the design f'_c. This is because the f'_c convergence is to within 10 psi.

Transformed Steel

Use of the TRNF card allows the user to include transformed compression and/or tension steel as a composite portion of the beam section. *PSTRS14* does not, however, include passive steel in the flexural strength calculations.

The additional cross sectional area due to the transformed compression steel is assumed to be equal to *[CC*(n - 1)*A]*, where *CC* is the entered compression steel coefficient, *n* is $E_s/(E_{c,beam})$, and *A* is the entered compression steel area. While *[(CC*n - 1)*A]* is theoretically more correct, historically *[CC*(n -1)*A]* has been used, and the difference between the two is insignificant.

The additional cross section area due to the transformed tension steel is assumed to be equal to *(n -1)*A*, the same as for compression steel without the coefficient.

The default for the compression steel modulus of elasticity E_s is 29,000 ksi, and the default for the tension steel E_s is 28,000 ksi for Standard specifications and 28,500 ksi for LRFD. Input options for these are on the MAT2 card.

The transformed tension steel option should not be used to transform the prestressing steel as this would yield incorrect results because of the way losses and camber are calculated within *PSTRS14*. Thus, when using transformed prestressing strands the elastic losses and camber must be handled differently than the program handles them [9].

Although input options are available in *PSTRS14* for the inclusion of transformed compression and tension steel in the cross section properties, the use of these options requires significant experience and judgment on the part of the user and is outside the usual practice for bridge design in Texas. Therefore, the consideration of transformed compression and tension steel is not standard practice and should not be used in *PSTRS14*.

Flexural Capacity (called "Ultimate Moment" in the Standard Specifications)

Flexural capacity provided to resist factored loads must be greater than or equal to the moment due to all factored loads and to the upper limit on cracking moment, whichever is greater. To avoid a brittle failure of the reinforcement in the case of lightly reinforced beams a lower limit on capacity is set to 1.2 M_{cr} (for all but LRFD 2012, which puts the limit at simply M_{cr} due to the fact that a flexural cracking variability factor of 1.6 is applied to the modulus of rupture, effectively taking the place of the 1.2 factor), but need not exceed 1.33 M_u. If the flexural capacity provided is less than required, the design algorithm of *PSTRS14* adds prestressing strands in increments of two (or four in the case of double-T beams) until the required minimum flexural capacity is achieved.

Where minimum capacity is met and additional flexural demand remains, if the maximum number of strands for the given section has been added or if the algorithm has determined that additional strands will not result in additional capacity, *PSTRS14* will incrementally increase the concrete strength and re-check the flexural capacity. If the concrete strength required reaches 20 ksi and the required flexural capacity is still not satisfied, an error message will be output and no design will be produced.

Passive reinforcement (compression and tension) is ignored in the calculation of flexural capacity.

Cracking Moment Equations

For Standard Specifications and LRFD thru the 3rd Edition (2004) the cracking moment equation used in *PSTRS14* is as follows:

$$M_{cr} = \left(f_r + f_{pe}\right)S_c - M_{d,nc}\left(\frac{S_c}{S_b} - 1\right) - M_i\left(\frac{S_c}{S_i} - 1\right) \quad \geq f_r S_c \text{ (for LRFD specs thru 2010)}$$

where,

f_r = Modulus of rupture = $7.5\sqrt{f'_c\,(psi)}$.

f_{pe} = Compressive stress in concrete due to effective prestress force only (after allowance for all prestress losses) at extreme fiber of section where tensile stress is caused by externally applied loads.

$M_{d,nc}$ = Midspan non-composite dead load moment.

M_i = Midspan dead load moment(s) resisted by each S_i.

S_b = Non-composite section modulus for bottom fiber of section.

S_c = Final composite section modulus for bottom fiber of section.

S_i = Section modulus resisting each M_i, for bottom fiber of section.

The flexural capacity of at least 1.2 times the cracking moment satisfies the minimum steel requirement intended to guard against fracture of the prestressing steel immediately after the cracking of the concrete. The cracking moment equation is derived by assuming that the extreme fiber tensile stress is equal to the modulus of rupture of the concrete.

Beginning with the 2005 Interim of the LRFD 3rd Edition (2004), the provisions of 5.4.2.6 increased the modulus of rupture, f_r, from $0.24\sqrt{f'_c\,(ksi)}$ $\left(7.6\sqrt{f'_c\,(psi)}\right)$ to $0.37\sqrt{f'_c\,(ksi)}$

$\left(11.7\sqrt{f'_c\,(psi)}\right)$ for use in the cracking moment equation for the purpose of meeting the minimum reinforcement requirement. However, TxDOT did not adopt this change in its LRFD Bridge Design Manual and thus PSTRS14 uses one modulus of rupture value of $7.5\sqrt{f'_c\,(psi)}$ for LRFD design thru 2010. For the case of a non-composite section, the cracking moment reduces to $M_{cr} = (f_r + f_{pe})S_b$.

For LRFD 6th Edition (2012), the cracking moment equation used in *PSTRS14* is as follows:

$$M_{cr} = \gamma_3\left[\left(\gamma_1 f_r + \gamma_2 f_{cpe}\right)S_c - M_{d,nc}\left(\frac{S_c}{S_b} - 1\right) - M_i\left(\frac{S_c}{S_i} - 1\right)\right] \text{(for LRFD 2012 specs)}$$

where,

f_r = Modulus of rupture = $0.24\sqrt{f'_c\,(ksi)}$.

f_{cpe} = Compressive stress in concrete due to effective prestress force only (after allowance for all prestress losses) at extreme fiber of section where tensile stress is caused by externally applied loads.

$M_{d,nc}$ = Midspan non-composite dead load moment.

M_i = Midspan dead load moment(s) resisted by each S_i.

S_{nc} = Non-composite section modulus for bottom fiber of section.

S_c = Final composite section modulus for bottom fiber of section.

S_i = Section modulus resisting each M_i, for bottom fiber of section.

γ_1 = flexural cracking variability factor (defaults to 1.6).

γ_2 = prestress variability factor (defaults to 1.1).

γ_3 = ratio of specified minimum yield strength to ultimate tensile strength of the reinforcement (defaults to 1.0).

Providing a flexural capacity of M_{cr} in LRFD 2012 satisfies the minimum steel requirement intended to guard against fracture of the prestressing steel immediately after cracking of the concrete. The cracking moment equation is derived by assuming that the extreme fiber tensile stress is equal to the upper limit on the range of moduli of rupture of the concrete and that there is a slight increase (10%) in the actual prestress induced stress over the otherwise calculated value. Since M_{cr} explicitly includes the variability in modulus of rupture there is no need to increase it by 20% to ensure against brittle reinforcement failure.

As compared to the LRFD 3rd Edition (2004) limit of $1.2M_{cr}$, the M_{cr} of LRFD 6th Edition (2012) will result in an increased minimum flexural capacity derived from a 33% increase in the modulus of rupture, a 8.33% decrease in prestress force, and a 16.67% decrease in the M_{cr} reducing effects of superimposed loads. The reason each component of M_{cr} is affected by this new definition of minimum flexural capacity is the removal of the 1.2 factor by which each component had previously been multiplied. If the user overrides the default values and inputs a value of 1.0 for γ_1 and γ_2 each and a value of 1.2 for γ_3 the minimum flexural capacity will match that of the previous AASHTO specifications. WARNING: The product of γ_3 and γ_1 should not be reduced below 1.2 when using the LRFD 2012 formulation since M_{cr} rather than 1.2 M_{cr} is used as the minimum flexural capacity.

The upper bound on M_{cr} of $1.33M_u$ is intended to avoid excessive amounts of bonded reinforcement where the factored moment is low and thus unlikely to crack the beam.

Web Width

The entry of a total effective web width on the SHRS card overrides the default width for all program calculations that use the web width. This is required input for non-standard beams.

Chapter 3 – Description of Input

General Input Information

- The term "card" is used herein to mean an 80-column line of input data that, except for the first two header cards, begins with a four-character alphanumeric identifier, a.k.a. command. The identifier is used by the program to establish the configuration of the data fields on the card, to instruct the program in the reading of these data fields and to launch a programed response to the data entered on the card. Thus the identifier can be considered a program command. All input cards have defined fields consisting of one or more columns where the input data is to be entered and from which it will be read by the program. One of three kinds of information (data types) may be entered in a field: alphanumeric, integer, or real.
- Numeric (integer or real) data may be entered in either English or Metric units. The program defaults to English units unless otherwise instructed (see the UNIT card input description).
- Alphanumeric (descriptive or symbolic) entries may include any letter of the alphabet, the digits 0 through 9, and the symbols / + - . ( ) $ * , = # % @ or blank. Alphanumeric data entries must usually be left justified.
- Integer entries may include the digits 0 through 9, the minus sign and the blank. Integers must be right justified within the input field. Blanks, if any, are limited to the leftmost columns of the field.
- Real numbers may include the digits 0 through 9, the minus sign, the decimal point and the blank. Each real number field has an implied decimal, so there is no need to enter a decimal point to indicate the division between the integral and fractional parts of the number if the number is entered such that the integral part ends (and fractional part begins) at the implied decimal. However, a data field with no decimals can be hard for a "human" to "read". An entered decimal overrides an implied decimal, but takes up one available column in the field and thus decreases by one the largest magnitude, and the number of significant figures, that can be entered in the field.
- If a field is entirely blank, it is defined as the program default, if a default exists for the field, or as no entry if no default exists. It is never interpreted as 0, unless the default is 0.
- An entry in a field is ignored if it is not applicable.
- A dollar sign ($) placed in column one of any row causes the program to ignore that row for input. This is useful for placing comments in the input file. These comments, of course, are not necessary for the program to operate on the input file data and can make the input look more complicated than it actually is.
- The cards are stored in an input file. A "run" is the submission of this input file to *PSTRS14* and the program's production of associated output files.
- Once the input file is prepared for a *PSTRS14* run, it can be run by simply dragging and dropping the input data file onto the *PSTRS14* shortcut located on the user's desktop. Program output will be stored in the same directory/folder as this input file.
- The input file can also be run by launching the program (double clicking the shortcut, or selecting the program from the Start menu) and entering the full directory path and

filename (e.g. c:\TxDOT\PSTRS14\Examples\Example1.dat) at the on-screen prompt. Note that if the input file is in the same directory as the shortcut, or in the directory pointed to by the “Start in” property of the shortcut, only the filename need be entered (e.g. Example1.dat).

- A third way of running an input file through *PSTRS14* is to run *PSTRS14* from the command prompt (invoked by Start>Run>cmd). At the command prompt, type “PSTRS14 DRIVE:\PATH TO YOUR DATA\InputFile.dat” where the “DRIVE”, “PATH” and “InputFile” names are associated with the input file to be run.
- Normally the most efficient way to run *PSTRS14* is the drag and drop method where the previously created and properly prepared input file is stored in a folder of the user’s choice and the user drags the input file from the folder and drops it on top of the *PSTRS14* desk top icon. This should not move the input file out of its folder. If it does the input file was not dragged to the *PSTRS14* icon but rather to the desktop. If dragged and dropped properly, *PSTRS14* will automatically run and place the resulting output files in the same folder in which the input file resides.
- Windows batch files (also called scripts or batch programs) may be used as an efficient way to automate the processing of many input files. A batch file is a text file (flat file) with .bat or .cmd file name extension that contains one or more commands. When you double-click a batch file or type the file name at the command prompt, the Windows command interpreter, Cmd.exe, runs the commands sequentially as they appear in the file. The ZIP archive "PSTRS14 Example Files.zip", in the "Examples" folder, contains two such batch files, PSTRS14_run_all.bat and PSTRS14_run_examples.bat. The PSTRS14_run_all.bat script is coded to automatically run every input file that resides in the same directory as the batch file. This batch file can be run as is without modification by the user. The PSTRS14_run_examples.bat script is coded to run selected input files. This batch file must be modified by the user prior to use. Both files include detailed information about how to use each script. You may view the information by opening the files using any text editor (e.g. *Notepad*, which comes with the Windows OS, or *Programmers’ File Editor (PFE)*, which is freeware available from the Internet). Any text editor will work for editing batch files but for coding *PSTRS14* input files *PFE*, or any editor that displays the row and column location of the cursor, is recommended because the display of the row and column location of the cursor is helpful for coding fixed field card based input data such as that for *PSTRS14*.
- Detailed explanations of input for each card are provided after this general information section. The specific columns for each data entry field are given, followed by a description of the input for that field. Default values, if any, are shown in parentheses after each description.
- An input form is shown for each card. Note that implicit decimals are shown in the fields where real numbers are to be entered. If a field is alphanumeric, the allowed entries are shown (for example, “LR or SR”). If there is no implied decimal and a unit is specified (for example, "in or mm"), an integer is to be entered.
- The number of cards in an input file depends on the number of beams being designed or analyzed and on the use of program defaults and optional cards. For example, if only one beam is being designed and if all the program defaults are used, a minimum of four cards are necessary: three header cards and a BEAM card. However, the program allows up to 200 beams to be designed or analyzed in one run. If all defaults are used, the minimum

number of cards for the maximum number of beams is 203 - 3 header cards and 200 BEAM cards. Sample card inputs are shown below:

(minimum 4 cards)	**(minimum of 203 cards)**	**(total cards indeterminate)**
Header #1	Header #1	Header #1
Header #2	Header #2	Header #2
PROB or Header #3	PROB or Header #3	PROB or Header #3
BEAM #1	BEAM#1	UNIT
	BEAM #2	MAT 1
	BEAM #3	SPEC
	BEAM #4	BEAM #1
	. . .	PROB #2
	. . .	ACAM
	. . .	ANLY
	BEAM #200	CGSL
		BEAM #2
		PROB #3
		. . .
		. . .
		. . .
		BEAM #200

Card Categories

There are two categories of input cards, cards that are cumulative and cards that are non-cumulative.

Cumulative Cards

Cumulative cards are cards that may be entered more than once for each BEAM card. These cards should be consecutive and must be entered before the BEAM card to which they apply. These cards do not carry over to the next BEAM card and include the following:

- CPR1	- LOAD/LOCL	- STPR/LOCR
- CPR2	- LVEC/LOCL	- TRNF (tension steel only)
- CPR3	- MSPR/LOCR	
- DBPR/LOCR	- NSCS	

Non-Cumulative Cards

The two subcategories of input cards that cannot be cumulative are (1) cards that must be input for each BEAM card and (2) cards that apply to all subsequent BEAM cards.

Cards that are not cumulative and must be input for each BEAM card do not carry over to the next BEAM card and must be entered before the BEAM card to which they apply. These include the following:

- ACAM	- LCCR	- SPEC
- ANLY	- LLDF (LRFD Only)	- TRNF (compression steel only)
- BEAM	- LVEU/LOCL	- UFAC
- CGSL	- OPTL	- USGC

Cards that cannot be cumulative and apply to all subsequent BEAM cards must be entered before the first BEAM card to which they apply. If a subsequent card of the same name is encountered, the new values replace the values from the previous card. These include the following:

- MAT1	- OUTP	- STRD
- MAT2	- SHRS	- UNIT

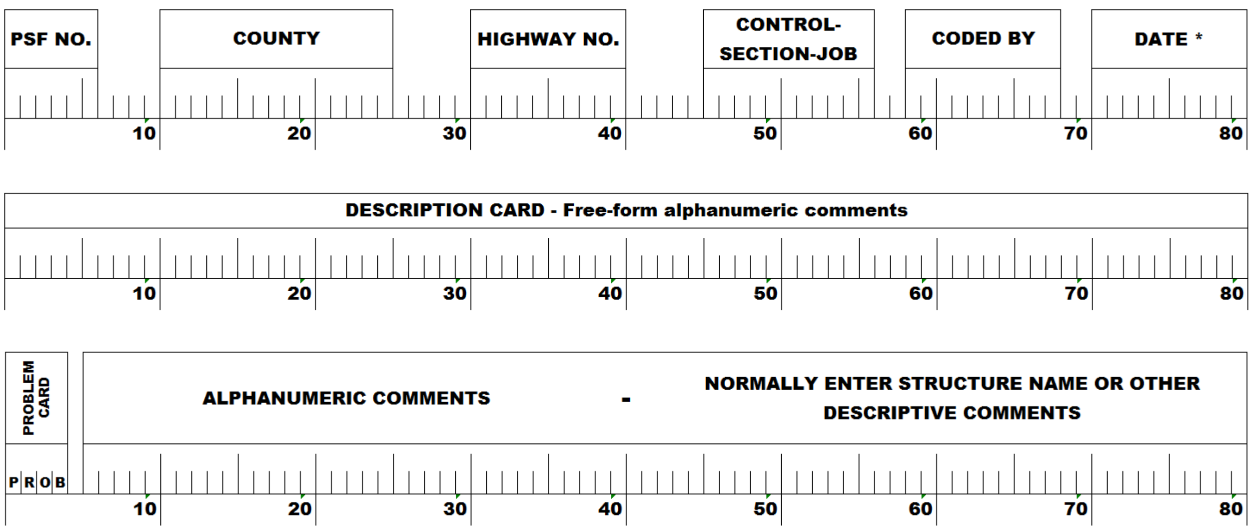
If more than one non-cumulative card of a specific type (for example, STRD) is entered for a single BEAM card, the last one entered will be used in the design or analysis process and the previous ones will be ignored. For example, if two STRD cards are entered before a BEAM card is entered, the first STRD card is ignored and the second STRD card is used.

Header Cards

There must be three header cards at the start of each input file. Either of the two sets of header cards described below may be used.

Header Cards Option 1

Two header cards are entered once at the start of each input file. The third header card, the PROB card, must be entered following the first two header cards, and may or may not be entered for each BEAM card thereafter. In spite of the suggested fields the header cards may contain any date, or can be blank (but must they be present). However, the field names and locations shown on the first header card will be printed near the top of the output regardless of the card's content.



Card Number 1:

Columns	Description
<1-6>	Optional accounting number or Shop Plan File No.
<11-25>	County (Optional)
<31-40>	Highway No. (Optional)
<46-56>	Control-Section-Job (Optional)
<59-68>	User's name or initials (Optional)
<70-80>	Date (default is the current date, which is retrieved from the computer)

Card Number 2:

Columns	Description
<1-80>	Alphanumeric descriptive information

Card Number 3:

Columns	Description
<1-4>	"PROB" - Problem card identifier. The BEAM cards that follow are identified with it in the output until a new PROB card is encountered.
<6-80>	Alphanumeric descriptive information

Header Cards Option 2

These three header cards contain alphanumeric identification for the entire run. Any descriptive data desired by the user may be entered on these cards or they may be left as blank lines. They must, however, be present, meaning that the file must contain three lines before the first line of non-header card input. All data on these first three cards will be printed to the output file as header information.

Card Number 1, 2 and 3:

Columns	Description
<1-80>	Alphanumeric descriptive information (if columns 70-80 of the first card is blank, the current date is retrieved from the computer)

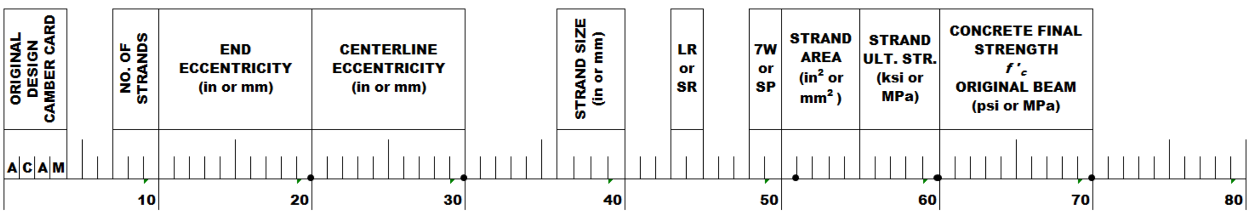
ACAM – Original Beam Design Camber Analysis

(analysis only)
(non-cumulative, no carry-over)

The total number of prestressing strands, the eccentricity of the strands at beam ends and at the centerline, and the prestressing strand and concrete properties of the original beam design may be entered on the ACAM card. This input is used for the calculations of the predicted camber of the original beam design and for comparison with the predicted camber of the beam being analyzed.

Error! Reference source not found.**Appendix A – Table 1 and Figure 1 thru Figure 19** Error! Reference source not found.gives the standard strand types available in *PSTRS14*. The following **Error! Reference source not found.** is a detailed description of the input options for strand size, type, area and strength.

Note: A fatal error occurs if no entry is made in cols. 8-30. A fatal error also occurs if no entry is made in cols. 61-70 of the ACAM card and no entry is made in cols. 11-20 of the MAT1 card. Defaults are shown in parentheses.



Columns	Description (defaults are shown in parentheses)
<1-4>	"ACAM" – Original beam camber card identifier
<8-10>	Total number of prestressing strands (no default, an entry is required)
<11-20>	Eccentricity of strands at ends of beam, in. or mm (no default, an entry is required)
<21-30>	Eccentricity of strands at centerline of span, in. or mm (no default, an entry is required)
<37-40>	Size of strand, left justified, in inches or mm. A standard strand size, as shown in**Error! Reference source not found.** of **Appendix A – Table 1 and Figure 1 thru Figure 19**Error! Reference source not found., or a non-standard strand size, may be entered. Allowable standard strand size entries are 1/4, 5/16, 3/8, 7/16, 1/2, 9/16, .600, and .700. A non-standard strand size entry must be in decimal form. A standard strand area entered in cols. 51-55 overrides the strand size entered in this field. (The default is dependent on user input; it is 1/2 if no entry is made in cols. 51-55.)
<44-45>	Strand type indicator LR {low relaxation} or SR {stress-relieved} (LR)
<49-50>	Strand type indicator 7W {7-wire} or SP {special} (7W)
<51-55>	Area of strand, in^2 or mm^2. A standard strand area, as shown in Table 1 of

Error! Reference source not found.**Appendix A – Table 1 and Figure 1 thru Figure 19**Error! Reference source not found., in this field overrides the area of the strand size input in cols. 37-40. (The default is dependent on user input; it is 0.153 or 98.7 if no entries are made in cols. 37-40, 49-50, and 56-60)

<56-60> Ultimate strength of strand, ksi or MPa (270. or 1860.)

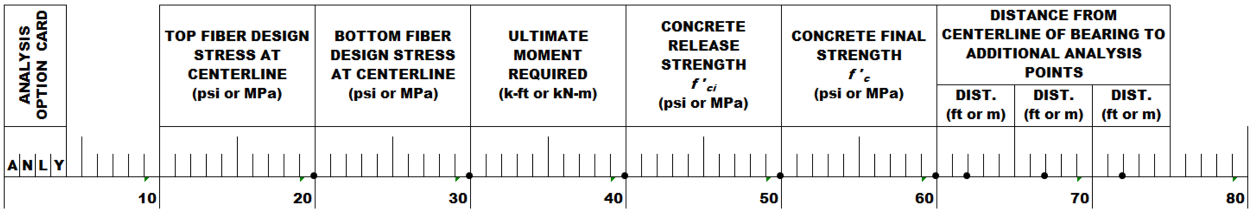
<61-70> Final concrete strength of original beam, psi or MPa. (An entry is required if no entry is made in cols. 11-20 of the MAT1 card.)

ANLY – Analysis Option

(analysis only)
(non-cumulative, no carry-over)

Design stresses**,** required ultimate moment, release and final beam concrete strengths and optional analysis points are entered on the ANLY card.

A fatal error occurs if no entry is made in at least one field of cols. 11-60.



Columns	**Description**
<1-4>	"ANLY" – Analysis option card identifier
<11-20>	Beam top fiber stress at centerline, due to total external load, psi or MPa (no default, an entry is required)
<21-30>	Beam bottom fiber stress at centerline, due to total external load, psi or MPa. A negative sign {-} must be entered for the tension (no default, an entry is required)
<31-40>	Ultimate moment required, k-ft or kN-m (no default, an entry is required)
<41-50>	Specified beam concrete release strength f'_{ci}, psi or MPa (no default, an entry is required)
<51-60>	Specified beam concrete final strength f'_c, psi or MPa (no default, an entry is required)
<61-65>	Distance from centerline of bearing to additional analysis point[4], ft or m (no default)
<66-70>	Distance from centerline of bearing to additional analysis point[2], ft or m (no default)
<71-75>	Distance from centerline of bearing to additional analysis point[2], ft or m (no default)

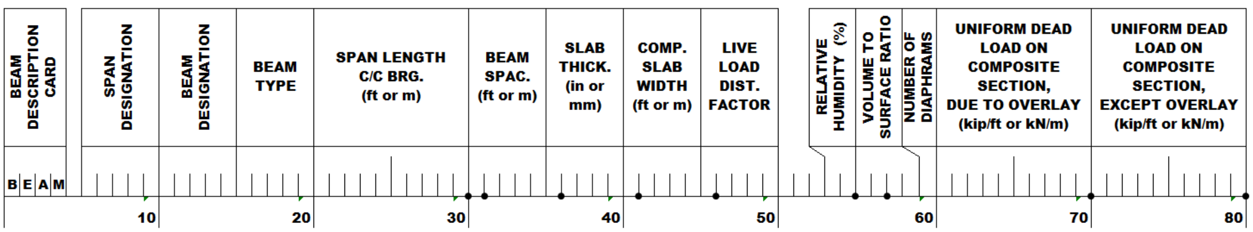
[4] These points are in addition to the standard locations 0.1L, 0.2L, 0.3L, etc.

BEAM – Basic Beam Description

(non-cumulative, no carry-over)

If the program default values are used, the three header cards and the BEAM card are the only cards required to design a standard beam using the Standard Specification. For LRFD, the LLDF card is also required for all beams as is the SPEC card. A maximum of 200 BEAM cards may be entered per run. Any optional cards must precede the BEAM card to which they apply. *PSTRS14* begins the design or analysis process when it encounters a BEAM card (an exception to card order occurs when a BEAMF card, rather than a BEAM card, is used).

A fatal error occurs if no or improper entry is made in cols. 16-35 for all beams, in cols. 46-50 for standard Box beams, U beams, Double-T beams, Double-HT beams, Slab beams, Decked Slab beams, X beams and non-standard beams using the Standard Specification, and all beams using LRFD, or in cols. 54-55−unless prestress losses are entered on the SPEC card.



Columns	**Description** (defaults are shown in parentheses)
<1-4>	"BEAM" – Beam card identifier
<6-10>	Alphanumeric span designation (no default)
<11-15>	Alphanumeric beam designation (no default)
<16-20>	Beam type. May be any standard I, Box, U, Double-T, Double-HT, Slab Decked Slab, and X beam, or TxGirder {IV, 4B40, U54, 6T22, 6HT36, 4SB15, 7DS20, 4X34, TX28, etc.} as shown in Figure 1 through Figure 19, or a non-standard beam {NS}. (no default, an entry is required)
<21-30>	Span length, c/c of bearing, ft or m (no default, an entry is required)
<31-35>	Beam spacing, ft or m (no default, an entry is required)
<36-40>	Slab thickness, in. or mm (0.0)
<41-45>	Composite slab width, ft or m {lesser of 12 x slab thickness + beam top flange width, 1/4 span length, or beam spacing for Standard Specification; and simply beam spacing for LRFD for all standard beams}. (entry required for non-standard beams if a slab thickness is entered or if CPR1 with haunch is entered)
<46-50>	Live load distribution factor. For the AASHTO Standard Specification, distribution of axle load is beam spacing divided by 11 for standard I beam and TxGirder (entry is required for all other standard beams and non-standard beams); For LRFD specifications this field is similarly used for entry of the live load distribution factor for moment and an entry is

required for all beam types. The LRFD live load distribution factor for shear is entered on the LLDF card which must be entered prior to the BEAM card to which it applies.

<54-55> Relative humidity, percent. If lump sum prestress losses are entered on the SPEC card relative humidity may not be entered for the same beam. (no default, an entry is required unless lump sum initial and final prestress losses are entered on the SPEC card)

<56-59> Volume-to-surface {v/s} ratio of section. This is used for prestress loss computations using the refined loss methodology that was introduced in the LRFD 2007 Specification. The slightly smaller calculated v/s ratio displayed in the program output listing is calculated internally by considering full beam surface area including beam ends, using this conversion formula: RS*L/(L+2*RS), where RS is the volume-to-surface ratio of the section and L is the physical length of the beam. (values are defined in the program's internal section library for standard beams; no default for NS beams)

<60> Number of Diaphragms. The number of diaphragms is only considered if TxDOT Standard I-Beams are used. It is ignored for all other beams. (0)

<61-70> Uniform dead load on composite section, due to overlay. This load will be included in stress calculations, but is excluded from AASHTO 2007 LRFD and TxDOT 2012 prestress loss calculations because it is considered a future load of unknown time of application. kip/ft or kN/m (no default)

<71-80> Uniform dead load on composite section, excluding overlay, kip/ft or kN/m (no default)

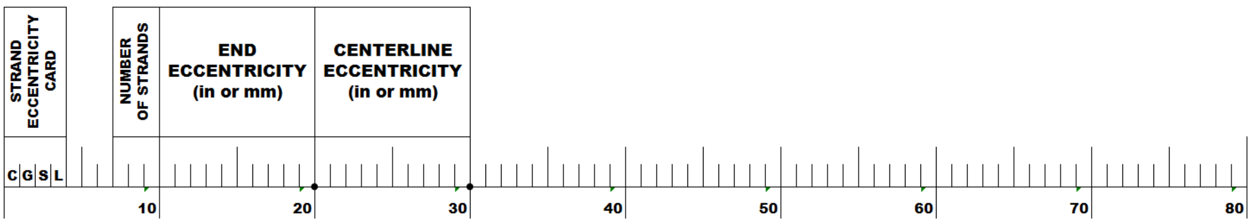
CGSL – Prestressed Strand Eccentricity

(analysis only)
(non-cumulative, no carry-over)

The total number of prestressing strands and the eccentricity of the strands at the ends and the centerline of the beam may be entered on the CGSL card.

The CGSL card is only applicable for the analysis of draped strand patterns or straight strand patterns with no debonding. STPR/LOCR and DBPR/LOCR cards cannot be used with the CGSL card. Either the CGSL card or the STPR/LOCR card set is required for analysis.

Since the CGSL card is used for both draped strands and straight strand patterns, there is no way to find out the area of strands on the “flexural tension side” at each tenth location. Therefore, all the strands are used in the calculation for area of strands in the “flexural tension side.”



Columns	**Description**
<1-4>	“CGSL” – Strand eccentricity card identifier
<8-10>	Total number of prestressing strands, (no default, an entry is required, right alignment)
<11-20>	Eccentricity of strands at ends of beam, in. or mm (no default, an entry is required)
<21-30>	Eccentricity of strands at centerline of span, in. or mm (no default, entry required)

See example on next page.

Example:

The following strand pattern:

```
No. of Strands, Total    =     58
Eccentricity at CL (in)  =  18.68
Eccentricity at End (in) =  10.41

Dist from Bott (in)  =   2.00   4.00   6.00   8.00  10.00  12.00
Strands/Row at End   =     10     10     10      8      6      2
Strands/Row at CL    =     12     12     12     10      8      4
Dist from Bott (in)  =  42.00  44.00  46.00  48.00  50.00  52.00
Strands/Row at End   =      2      2      2      2      2      2
Strands/Row at CL    =      0      0      0      0      0      0
```

Can be defined with either STPR/LOCR cards as follows:

```
STPR    CL   12   12   12   10    8    4
LOCR          2    4    6    8   10   12
STPR    ED   10   10   10    8    6    2    2    2    2    2    2    2
LOCR          2    4    6    8   10   12   42   44   46   48   50   52
```

Or with a single CGSL card like this:

```
CGSL    58     10.41     18.68
```

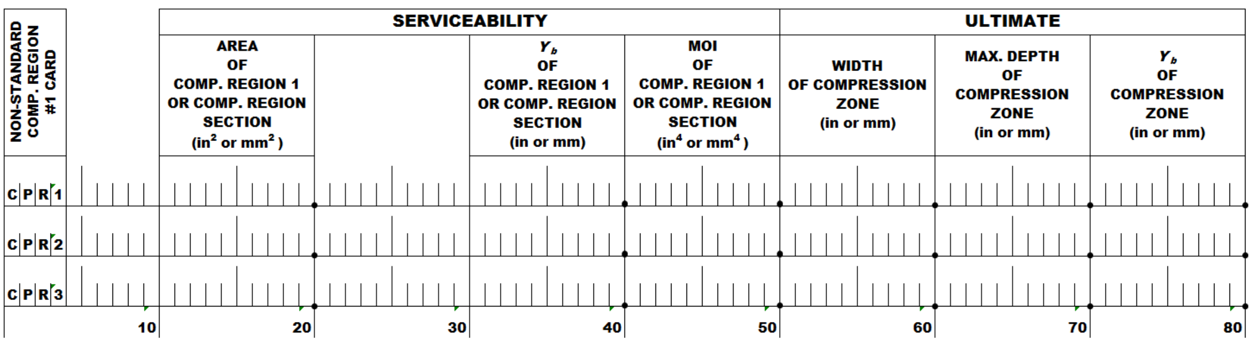
CPR1, CPR2, CPR3 – Non-Standard Composite Regions 1, 2, & 3 Description

(cumulative, no carry-over)

Cross section properties and compression zone dimensions for composite regions 1, 2 and 3 may be entered on the CPR1, CPR2 and CPR3 cards, respectively. The CPR1, CPR2 and CPR3 cards are applicable to, but not required for, non-standard beams. They are not applicable to standard I beams, Box beams, U beams, Slab beams, Decked Slab beams, TxGirders, Double-T beams and X beams. A total of fourteen NSCS, CPR1, CPR2 and CPR3 cards may be used in any combination for each BEAM card, but a maximum of three each of cumulative CPR1, CPR2 and CPR3 cards are recommended.

Serviceability requirements are entered in columns 11-50 and ultimate requirements are entered in columns 51-80. Serviceability and ultimate entries are independent of each other; therefore, if preferred, complete data for serviceability requirements may be entered on the first composite region card, with subsequent cumulative cards of that name having only entries for the remaining ultimate requirements.

Negative entries in any of these fields will cause erroneous calculations.



Columns	Description
<1-4>	"CPR1", "CPR2", "CPR3" – Composite region 1, 2 and 3 card identifiers, respectively
<11-20>	Area of composite region or composite region section, in^2 or mm^2 (no default)
<31-40>	Distance from bottom of beam to centroid of composite region or composite region section, in. or mm (no default)
<41-50>	Moment of inertia of composite region or composite region section, in^4 or 1x10^{-6} mm^4 (no default)
<51-60>	Width of ultimate bending moment compression zone of composite region or composite region section, in. or mm (no default)
<61-70>	Maximum depth of ultimate bending moment compression zone of composite region or composite region section, in. or mm (no default)
<71-80>	Distance from bottom of beam to centroid of compression zone of composite region or composite region section, in. or mm (no default)

DBPR & LOCR – Debonded Prestressing Strand Pattern

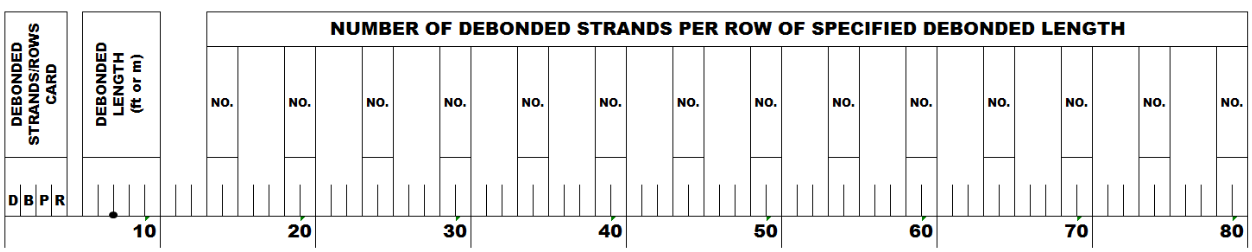
(analysis only)
(cumulative, no carry-over)

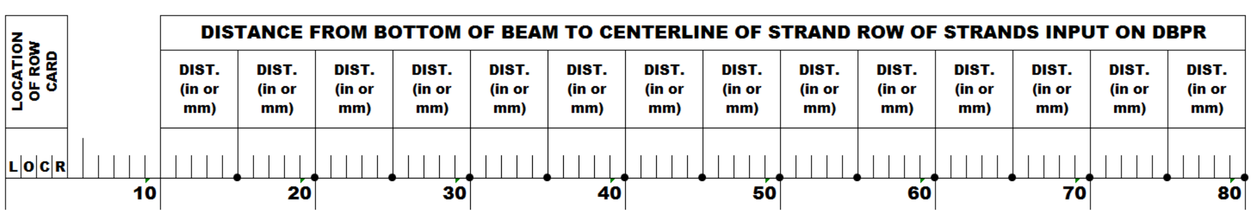
The number of debonded strands per row of a specified debonded length and the distance from the bottom of the beam to the centroid of each row may be entered on the DBPR/LOCR cards. A maximum of three sets of DBPR/LOCR cards for each of 10 different debonded lengths is allowed for each BEAM card. Therefore, a total of 30 sets of DBPR/LOCR cards (14 rows per card, to a maximum of 35 rows per debonded length) are allowed per BEAM card. Cards must be entered in ascending order from the end of the beam towards midspan.

The STPR/LOCR cards, with “CL” entered in cols. 9-10 must be input before the DBPR/LOCR cards. The CGSL card cannot be used with the DBPR/LOCR cards.

If the STRD card is required, it must be placed before the first DBPR card. Debonded lengths entered on the DBPR cards must be even multiples of the debonding increment, which is a real number. If a value other than the default (3.0 ft) is required, it is entered in cols. 76-80 of the STRD card. For standard I, TxGirder and non-standard beams with debonded strands, the STRD card is required with “WD” (With Debonding) entered in cols. 69-70.

A fatal error occurs if no entry is made in cols. 6-10 of the DBPR card and if “WD” is entered in cols. 69-70 of the STRD card. If no entry is made in cols. 6-10 of the DBPR card and if “ND” is entered on the STRD card, the program assumes straight strands with no debonding.





Columns	Description
<1-4>	“DBPR” – Debonded strands per row card identifier
<6-10>	Debonded strand length, ft or m (entry required)
<14-15>	Number of debonded strands, of the specified debonded length, per row. This is the number of strands in the specified row that are debonded for the length specified in cols. 6-10 {for example, if 2 strands are debonded for 3’ and 4 strands are debonded for 9’ in the specified row, the number

entered for the 3' debonded length is 2, not 6}. The number of strands per row may be entered in fourteen successive 2-column fields, beginning in cols. 14-15 and ending in cols. 79-80. If a blank field of input is encountered the program reads it as the end of the input data for the card. Any data entered beyond the blank field will be ignored. (no default)

<19-20>,<24-25>,<29-30>,. . .,<79-80> Same as <14-15> above.

Each DBPR card must be immediately followed by a corresponding LOCR card.

Columns	**Description**
<1-4>	"LOCR" – Row location card identifier
<11-15>	Distance from bottom of beam to centroid of strand row, in. or mm. The distance to each row for the number of strands input on the preceding DBPR card must be entered in the successive 5-column fields, beginning in cols. 11-15 and ending in cols. 76-80. An entry must be made on this card for each field on the DBPR card. Input must be in order of increasing distance. If a blank field of input is encountered the program reads it as the end of the input data for the card. Any data entered beyond the blank field will be ignored. (no default)

<16-20>, <21-25>, <26-30>, …, <76-80> same as <11-15> above.

Example:

The following debonding pattern output into a .sms CAD file,

Y_b of Strands	Num Strands /Row	Num Debonded /Row	Debond to 3 ft	Debond to 6 ft	Debond to 9 ft	Debond to 12 ft	Debond to 15 ft	Debond to 18 ft
2.17	27	20	0	6	8	4	2	0
4.14	27	14	10	4	0	0	0	0

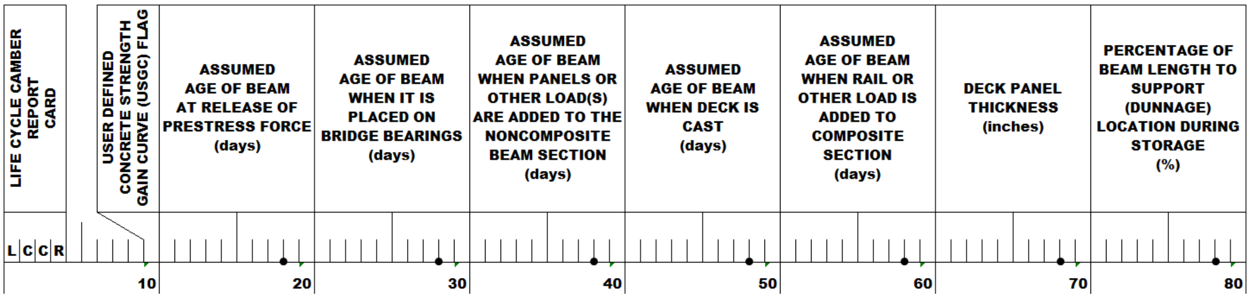
can be input with the following cards:

```
DBPR  3.0    10
LOCR       4.14
DBPR  6.0     6    4
LOCR       2.17 4.14
DBPR  9.0     8
LOCR       2.17
DBPR 12.0     4
LOCR       2.17
DBPR 15.0     2
LOCR       2.17
```

LCCR – Optional Life-Cycle Camber Report

(non-cumulative, no carry-over)

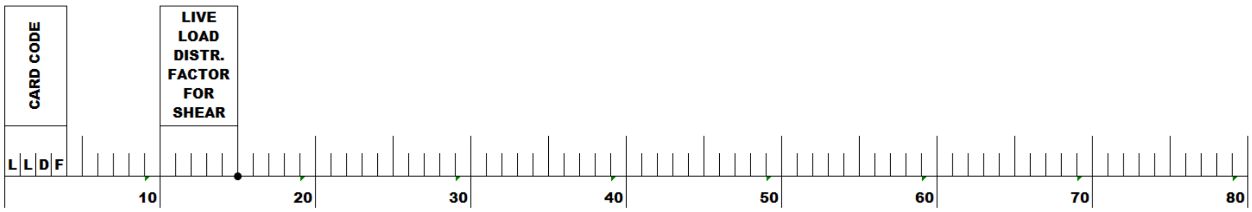
To produce the optional Life Cycle Camber Report this card must be present for each beam for which such a report is requested. No data entry is required unless the user wishes to override any of the defaults.



Columns	**Description** (defaults are shown in parentheses)
<1-4>	“LCCR” – Life Cycle Camber Report optional data card.
<10>	Flag to indicate that user will input array values of age and concrete strength: 0 or blank = Do not read values (use default values instead) 1 = Read values from the USGC card(s)
<11-20>	Age of the beam {days} at release of prestress force (TIME FROM STRESSING TO TRANSFER entered on SPEC Card divided by 24 to covert to days; 1.0 if SPEC Card columns 74-75 is empty or no SPEC Card is present)
<21-30>	Age of the beam {days} when placed in the bridge (10 days less than TIME TO DECK CONCRETE PLACEMENT entered on SPEC Card; 110 if SPEC Card columns 71-73 are empty or no SPEC Card is present)
<31-40>	Age of the beam {days} when the superimposed load is added to the noncomposite member, e.g. when deck panels are placed (5 days less than TIME TO DECK CONCRETE PLACEMENT entered on SPEC Card; 115 if SPEC Card columns 71-73 are empty or no SPEC Card is present)
<41-50>	Age of the beam {days} when the composite slab is cast (TIME TO DECK CONCRETE PLACEMENT entered on SPEC Card; 120 if SPEC Card columns 71-73 are empty or no SPEC Card is present)
<51-60>	Age of the beam {days} when the superimposed load is added to the composite member, e.g. asphalt overlay (60 days more than TIME TO DECK CONCRETE PLACEMENT entered on SPEC Card; 180 if SPEC Card columns 71-73 are empty or no SPEC Card is present)
<61-70>	Precast deck panel thickness in inches (0.0)
<71-80>	Distance to storage-support {dunnage} location in % of beam physical length (3.0)

LLDF – Live Load Distribution Factor for Shear

(AASHTO LRFD only)
(non-cumulative, no carry-over)



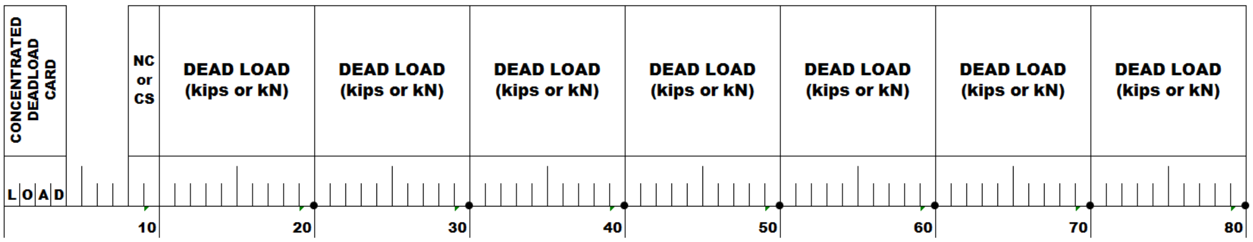
Columns	**Description** (default is shown in parentheses)
<1-4>	"LLDF" – Live load distribution factor card identifier.
<11-15>	Live load distribution factor for shear {for AASHTO LRFD spec only}. Use BEAM card for input of live load distribution factor for flexure. (0.0)

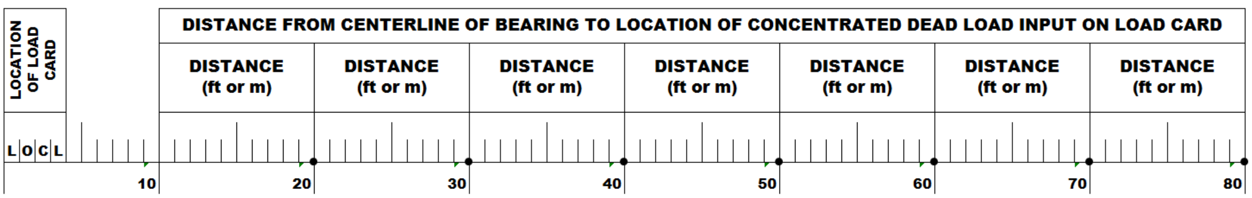
LOAD & LOCL – Concentrated Dead Loads

(cumulative, no carry-over)

Concentrated dead loads on the non-composite and/or composite section may be entered on the LOAD/LOCL cards. A maximum of two sets of LOAD/LOCL cards (a maximum of 7 loads per card for a total of 14 loads; only 12 loads for U beams) are allowed per BEAM card for each section type (i.e. two sets for non-composite sections and two sets for composite sections). Therefore, a maximum of four sets of loads is allowed per BEAM card. These cards may be used to enter diaphragm loads for standard Box and non-standard beams. Concentrated dead loads on composite sections will be included in stress calculations, but not included in AASHTO 2007 LRFD prestress loss calculations.

A fatal error occurs if no entry is made in cols. 9-10 of the LOAD card.





Columns	**Description**
<1-4>	"LOAD" – Dead load card identifier
<9-10>	Section type indicator NC {Non-composite} or CS {Composite} (no default, entry required)
<11-20>	Load, kips or kN. Concentrated loads may be entered in seven successive 10-column fields, beginning in cols. 11-20 and ending in cols. 71-80. If a blank field of input is encountered the program reads it as the end of the input data for that card. (no default)

<21-30> ,<31-40> ,<41-50> ,<51-60>,<61-70>,<71-80> same as <11-20> above.

Each LOAD card must be immediately followed by a corresponding LOCL card.

Columns	**Description**
<1-4>	"LOCL" – Load location card identifier
<11-20>	Distance from left centerline of bearing to load, in ft or m. A location must

be given for each load entered on the preceding LOAD card and in the corresponding order; these locations must be entered beginning in cols. 11-20 and ending in cols. 71-80. If a blank field of input is encountered the program reads it as the end of the input data for the card. Any data entered beyond the blank field will be ignored. (no default)

<21-30>,<31-40>,<41-50>,<51-60>,<61-70>,<71-80> same as <11-20> above.

LVEC & LOCL – Non-Standard Concentrated Live Loads

(cumulative, no carry-over)

Non-standard concentrated live loads may be entered on the LVEC/LOCL cards. A maximum of 50 sets of LVEC/LOCL cards (a maximum of 7 loads per card for a total of 350 loads) is allowed per BEAM card.

NON-STANDARD CONCENTRATED LIVE LOADS CARD		LL TYPE INDICATOR	CONCENTRATED LIVE LOADS						
			LOAD MAGNITUDE (kips or kN)	LOAD MAGNITUDE (kips or kN)	LOAD MAGNITUDE (kips or kN)	LOAD MAGNITUDE (kips or kN)	LOAD MAGNITUDE (kips or kN)	LOAD MAGNITUDE (kips or kN)	LOAD MAGNITUDE (kips or kN)
L V E C									
		10	20	30	40	50	60	70	80

LOCATION OF LOAD CARD		DISTANCE FROM FIRST NON-STANDARD CONCENTRATED LIVE LOAD INPUT ON LVEC CARD						
		DISTANCE (ft or m)	DISTANCE (ft or m)	DISTANCE (ft or m)	DISTANCE (ft or m)	DISTANCE (ft or m)	DISTANCE (ft or m)	DISTANCE (ft or m)
L O C L								
	10	20	30	40	50	60	70	80

Columns **Description** (defaults are shown in parentheses)

<1-4> "LVEC" – Non-standard concentrated live load card identifier

<9-10> Live load type indicator (blank):

- blank {the maximum of the input non-standard concentrated live load and the input non-standard uniform live load entered on LVEU/LOCL cards. May be used to obtain a load similar to HS20. May also be used to simulate train loadings with concentrated loads for engine axles explicitly input via LVEC/LOCL cards and uniform load portion of train entered as a series of constant value concentrated loads rather than using LVEU/LOCL cards.}

- SP {superimposed loads; load superimposed with input non-standard uniform live load entered on LVEU/LOCL cards. Can be used to obtain a load similar to HL93.}

<11-20> Load, kips or kN. Non-standard concentrated live loads may be entered in seven successive 10-column fields, beginning in cols. 11-20 and ending in cols. 71-80. No impact factor is applied to these loads by the program. If an impact factor is required, the user must adjust the loads to include this impact or adjust the live load distribution factor to include the impact. For AASHTO LRFD designs, the impact should not be applied to the LLDF since it is not to be applied to the lane load portion. If a blank field of input is encountered the program reads it as the end of the input data for the card. Any data entered beyond the blank field will be ignored. (no default)

<21-30>, <31-40>, <41-50>, <51-60>, <61-70>, <71-80> same as <11-20> above.

Each LVEC card must be immediately followed by a corresponding LOCL card.

Columns	**Description**
<1-4>	"LOCL" – Load location card identifier
<11-20>	Must enter 0.0
<21-30>	Distance from the first non-standard concentrated live load to the corresponding concentrated live load, ft or m. Location of each live load entered on the preceding LVEC card must be entered, beginning in cols. 21-30 and ending in cols. 71-80. The second corresponding input on its paired LOCL card will be the distance between the first and the second concentrated live loads. This will repeat for subsequent inputs. If a blank field of input is encountered the program reads it as the end of the input data for the card. Any data entered beyond the blank field will be ignored. (no default)

<31-40>,<41-50>,<51-60>,<61-70>,<71-80> same as <21-30> above.

Example:

HS20 truck load defined as a non-standard live load:
[L = 50 ft, therefore, Impact = 50 / (L + 125) = 0.286; apply to the live load distribution factor]

```
LVEC          8.0       32.0      32.0
LOCL          0.0       14.0      28.0
LVEU 18.0     0.640
LOCL        999.9
```

HL93 truck load defined as a non-standard live load:
[Dynamic Load Allowance = 0.33; apply to concentrated loads only]

```
LVEC    SP  10.64       42.56     42.56
LOCL          0.0       14.0      28.0
LVEU          0.640
LOCL        999.9
```

Cooper E80 train load defined as a non-standard live load:
[14 ft < L = 50 ft < 127 ft, therefore, Impact = $(225 / L^{1/2}) / 100$ = 0.318; apply to the live load distribution factor; model uniform load as concentrated loads at 5 ft increments]

```
LVEC      40.0      80.0      80.0      80.0      80.0      52.0      52.0
LOCL       0.0       8.0      13.0      18.0      23.0      32.0      37.0
LVEC      52.0      52.0      40.0      80.0      80.0      80.0      80.0
LOCL      43.0      48.0      56.0      64.0      69.0      74.0      79.0
LVEC      52.0      52.0      52.0      52.0      40.0      40.0      40.0
LOCL      88.0      93.0      99.0     104.0     111.5     116.5     121.5
LVEC      40.0      40.0      40.0      40.0      40.0      40.0      40.0
LOCL     126.5     131.5     136.5     141.5     146.5     151.5     156.5
LVEC      40.0      40.0      40.0      40.0      40.0      40.0      40.0
LOCL     161.5     166.5     171.5     176.5     181.5     186.5     191.5
```

LVEU & LOCL – Non-Standard Uniform Live Loads

(non-cumulative, no carry-over)

Non-standard uniform live loads may be entered on the LVEU/LOCL cards. A maximum of 7 consecutive variable-length uniform live load entries (one set of LVEU/LOCL cards) are allowed per BEAM card.

NON-STANDARD UNIFORM LIVE LOADS CARD	CONCENTRATED (POINT) LOAD (kips or kN)	UNIFORM LIVE LOAD						
		LOAD MAGNITUDE (kips/ft or kN/m)	LOAD MAGNITUDE (kips/ft or kN/m)	LOAD MAGNITUDE (kips/ft or kN/m)	LOAD MAGNITUDE (kips/ft or kN/m)	LOAD MAGNITUDE (kips/ft or kN/m)	LOAD MAGNITUDE (kips/ft or kN/m)	LOAD MAGNITUDE (kips/ft or kN/m)
L V E U	10	20	30	40	50	60	70	80

LOCATION OF LOAD CARD		LENGTH OF CORRESPONDING LIVE LOAD INPUT ON LVEU CARD						
		DISTANCE (ft or m)	DISTANCE (ft or m)	DISTANCE (ft or m)	DISTANCE (ft or m)	DISTANCE (ft or m)	DISTANCE (ft or m)	DISTANCE (ft or m)
L O C L	10	20	30	40	50	60	70	80

Columns	**Description** (defaults are shown in parentheses)
<1-4>	"LVEU" – Non-standard uniform live load card identifier
<5-10>	Concentrated live load on the span for lane loading, as specified in AASHTO, in kips or kN. For the calculation of the shear forces, this load is increased by 26/18 in *PSTRS14* to match the concentrated load that is part of the lane load used in AASHTO Standard specifications. No impact factor is applied to these loads. If an impact factor is required, then the user must adjust the loads to include impact. (0.0)
<11-20>	Uniform live load, kips/ft or kN/m. No impact factor is applied to these loads. If an impact factor is required, then the user must adjust the loads to include impact. Non-standard uniform live loads may be entered in seven successive 10-column fields, beginning in cols. 11-20 and ending in cols. 71-80. If a blank field of input is encountered the program reads it as the end of the input data for the card. (no default)

<21-30>, <31-40>, <41-50>, <51-60>, <61-70>, <71-80> same as <11-20> above.

Each LVEU card must be immediately followed by a corresponding LOCL card.

Columns	**Description**
<1-4>	"LOCL" – Load location card identifier
<11-20>	Length of the corresponding uniform live load on LVEU card, ft or m. Range of each uniform live load input on the preceding LVEU card must be entered, beginning in cols. 11-20 and ending in cols. 71-80. The first

corresponding input on its paired LOCL card of the LVEU/LOCL will be the length of the first uniform live load. The second corresponding input on its paired LOCL card will be the second uniform live load. This will repeat for subsequent inputs. If a uniform live load is to be applied to the entire span, a length greater than the span length can be entered, up to a max of 1550 ft. If a blank field of input is encountered the program reads it as the end of the input data for the card. Any data entered beyond the blank field will be ignored. (no default)

<21-30>,<31-40>,<41-50>,<51-60>,<61-70>,<71-80> Same as <11-20> above.

Example:

HS20 truck load defined as a non-standard live load:
[L = 50 ft, therefore, Impact = 50 / (L + 125) = 0.286; apply to the live load distribution factor]

```
LVEC          8.0       32.0      32.0
LOCL          0.0       14.0      28.0
LVEU 18.0     0.640
LOCL        999.9
```

HL93 truck load defined as a non-standard live load:
[Dynamic Load Allowance = 0.33; apply to concentrated loads only]

```
LVEC    SP  10.64       42.56     42.56
LOCL          0.0       14.0      28.0
LVEU          0.640
LOCL        999.9
```

Cooper E80 train load defined as a non-standard live load:
[14 ft < L = 50 ft < 127 ft, therefore Impact = $(225 / L^{1/2}) / 100$ = 0.318; apply to the live load distribution factor; model uniform load as concentrated loads at 5 ft increments]

```
LVEC      40.0      80.0      80.0      80.0      80.0      52.0      52.0
LOCL       0.0       8.0      13.0      18.0      23.0      32.0      37.0
LVEC      52.0      52.0      40.0      80.0      80.0      80.0      80.0
LOCL      43.0      48.0      56.0      64.0      69.0      74.0      79.0
LVEC      52.0      52.0      52.0      52.0      40.0      40.0      40.0
LOCL      88.0      93.0      99.0     104.0     111.5     116.5     121.5
LVEC      40.0      40.0      40.0      40.0      40.0      40.0      40.0
LOCL     126.5     131.5     136.5     141.5     146.5     151.5     156.5
LVEC      40.0      40.0      40.0      40.0      40.0      40.0      40.0
LOCL     161.5     166.5     171.5     176.5     181.5     186.5     191.5
```

MAT1 – Material Description No. 1

(non-cumulative, will carry-over)

Unit weights of concrete by element, moduli of elasticity of concrete by element, minimum release strength, minimum strength gain between release and final beam concrete strengths, tension coefficient for cracking moment, unit weight of slab concrete, final concrete strengths of slab and shear key or composite region 1, and beam modulus correction factor for aggregate source may be entered on the MAT1 card.

MATERIAL #1 CARD	UNIT WT. OF BEAM CONC. *(pcf or kg/m³)*	MODULUS OF ELASTICITY OF BEAM CONC. *(ksi or MPa)*	MIN f'_{ci} OF BEAM CONC. *(psi or MPa)*	MIN. STR. GAIN FROM f'_{ci} TO f'_c OF BEAM CONC. *(psi or MPa)*	TENS. COEFF. FOR M_{CR}	UNIT WT. OF SLAB CONC. *(pcf or kg/m³)*	MODULUS OF ELASTICITY OF SLAB CONC. *(ksi or MPa)*	f'_c OF SLAB CONC. *(psi or MPa)*	UNIT WT. OF KEY OR CPR1 CONC. *(pcf or kg/m³)*	MODULUS OF ELASTICITY OF KEY OR CPR1 *(ksi or MPa)*	f'_c OF KEY OR CPR1 *(psi or MPa)*	K_1 BEAM MOE CORR. FACT. FOR SOURCE OF AGGR.
MAT1												
	10	20		30		40	50		60	70		80

Columns	**Description** (defaults are shown in parentheses)
<1- 4>	"MAT1" – Material #1 card identifier
<6-10>	Unit weight of beam concrete, pcf or kg/m^3 (150. or 2403.)
<11-20>	Modulus of elasticity of beam concrete {$E_{c,\text{beam}}$}, ksi or MPa ([5])
<21-25>	Minimum beam concrete strength at release, psi or MPa (4000. or 27.579)
<26-30>	The minimum concrete strength gain between release and final. {$f'_{c\_minimum} = f'_{ci} + \textit{Minimum Strength Gain}$}, psi or MPa (0.0)
<31-35>	Tension coefficient used to calculate the modulus of rupture, f_r, for determining cracking moment, M_{cr}. $\{ f_r = \text{Tension Coefficient} * \sqrt{f'_c} \}$ (7.5 for f'_c in psi, 0.63 for f'_c in MPa, 0.24 for LRFD 2012)
<36-40>	Unit weight of slab concrete, pcf or kg/m^3 (150. or 2403.)
<41-50>	Modulus of elasticity of slab concrete {$E_{c,\text{slab}}$}, ksi or MPa ([3])
<51-55>	Final concrete strength of slab, psi or MPa (4000. or 27.579)
<56-60>	Unit weight of shear key or composite region 1 concrete, pcf or kg/m^3 (150. or 2403.)
<61-70>	Modulus of elasticity of shear key concrete {$E_{c,\text{key}}$} or composite region 1

[5] E_C calculated according to *AASHTO Standard specifications* 8.7.1. For a modular ratio of 1.0, input constant E_C (5000. ksi typical) for all sections.

$$E_c = 33{,}000 \cdot w_c^{1.5} \sqrt{f'_c}$$

concrete {E_c,CPR1}, ksi or MPa ([3])

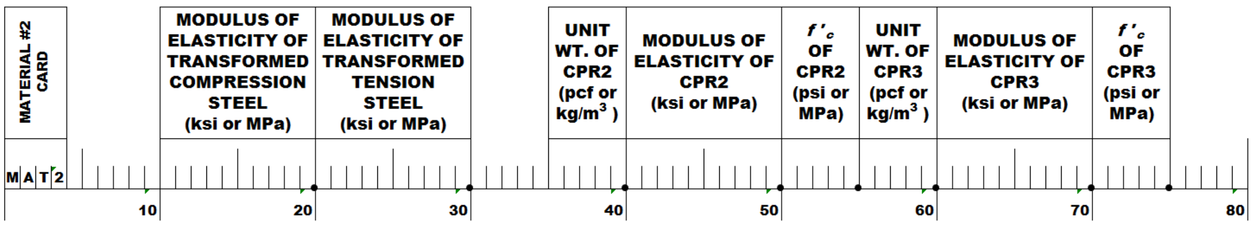
<71-75> Final concrete strength of shear key or composite region 1, psi or MPa (4000. or 27.579)

<75-80> Beam modulus of elasticity correction factor for aggregate source (1.0)

MAT2 – Material Description No. 2

(non-cumulative, will carry-over)

Unit weights of concrete for composite regions 2 and 3, moduli of elasticity and final concrete strengths for composite regions 2 and 3, as well as moduli of elasticity of transformed steel, may be entered on the MAT2 card.



Columns	**Description** (defaults are shown in parentheses)
<1- 4>	"MAT2" – Material #2 card identifier
<11-20>	Modulus of elasticity of transformed compression steel, ksi or MPa (29000. or 199948.)
<21-30>	Modulus of elasticity of transformed tension steel, ksi or MPa (28000. or 193053.)
<36-40>	Unit weight of composite region 2 concrete, pcf or kg/m^3 (150. or 2403.)
<41-50>	Modulus of elasticity of composite region 2 concrete {E_c,CPR2}, ksi or MPa (^{3})
<51-55>	Final concrete strength of composite region 2, psi or MPa (4000. or 27.579)
<56-60>	Unit weight of composite region 3 concrete, pcf or kg/m^3 (150. or 2403.)
<61-70>	Modulus of elasticity of composite region 3 concrete {E_c,CPR3}, ksi or MPa (^{3})
<71-75>	Final concrete strength of composite region 3, psi or MPa (4000. or 27.579)

MSPR & LOCR – Prestressing Strand Grid

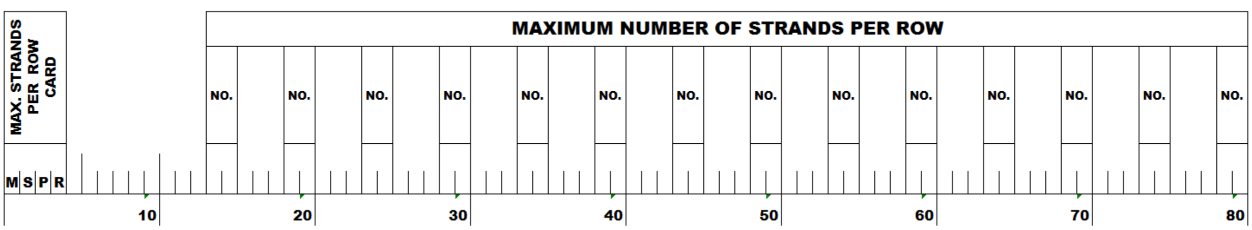
(design only)
(cumulative, no carry-over)

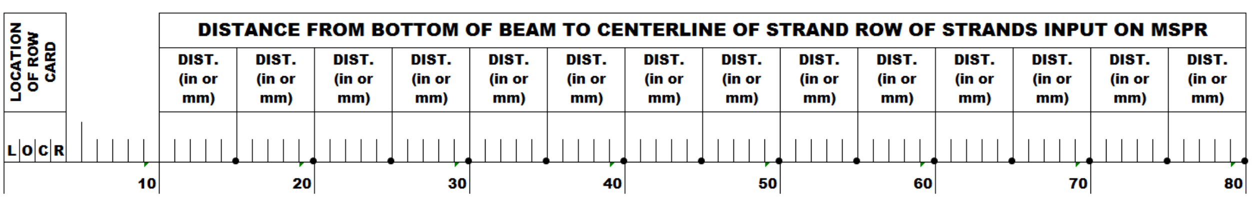
The maximum number of strands per row and the distance from the bottom of the beam to the centroid of each row may be entered on the MSPR/LOCR cards to define the strand grid of a non-standard beam section or a non-standard strand grid for a standard beam section. A maximum of three sets of MSPR/LOCR cards (14 rows per card, for a maximum of 35 rows) is allowed per BEAM card.

The MSPR/LOCR cards are applicable for design only. These cards are required for a non-standard beam and are optional for standard beams.

Standard beams have a strand grid based on a 2x2 inch grid, with the bottom row located 2.0 inches above the bottom of the beam for standard I and Double-T beams and 2.5 inches above the bottom of the beam for standard Box beams, Slab beams, Decked Slab beams, TxGirders and X beams. Standard U beams have a strand grid with the bottom row at 2.17 in from the bottom and subsequent rows spaced at 1.97 in. See Figure 12 in **Appendix A – Table 1 and Figure 1 thru Figure 19**.

Since the strand grid for 0.600” strands is different than the standard grid for 0.500” strands, MSPR/LOCR cards must be present when 0.600” strands are used in TxGirders. Likewise MSPR/LOCR cards must be used for any other standard beams that have a strand grid different from the standard grid for 0.500” strands.





Columns	Description
<1-4>	“MSPR” – Maximum strands per row card identifier
<14-15>,…	Maximum number of strands per row. Number of strands per row may be entered in fourteen successive 2-column fields, beginning in cols. 14-15 and ending in cols.79-80. If a blank field of input is encountered the program reads it as the end of the input data for the card. Any data entered beyond the blank field will be ignored. (no default)

<19-20>,<24-25>,<29-30>,...,<79-80> same as <14-15> above.

Each MSPR card must be immediately followed by a corresponding LOCR card.

Columns	Description
<1-4>	"LOCR" – Row location card identifier
<11-15>,...	Distance from bottom of beam to centroid of strand row, in. or mm. The distance to each row for the number of strands entered on the preceding MSPR card must be entered in the successive 5-column fields, beginning in cols. 11-15 and ending in cols. 76-80. Entries must be made in the order of increasing distance. Blanks between fields of input data are not allowed; the program reads a blank field as the end of input data for that card. (no default)

<16-20>,<21-25>,<26-30>,...,<76-80> same as <11-15> above.

Example:

Definition of a Type A Beam Strand Pattern

```
MSPR          6    6    4    2    2    2    2    2    2    2    2    2    2
LOCR        2.0  4.0  6.0  8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0
```

<u>**NSCS – Non-Standard Cross Section Description**</u>

(cumulative, no carry-over)

Cross section properties and compression zone dimensions for a non-standard beam are entered on the NSCS card. The NSCS card is required for a non-standard beam, and is not applicable to standard I beam, Box beam, Slab beam, Decked Slab beam, Double Tee beam, U beam, TxGirder and X beam sections. A total of fourteen NSCS, CPR1, CPR2 and CPR3 cards may be used in any combination for each BEAM card but it is recommended that a maximum of five cumulative NSCS cards be used.

Serviceability requirements are entered in columns 11-50 and ultimate requirements are entered in cols. 51-80. Serviceability and ultimate entries are independent of one another; therefore, if preferred, complete data for serviceability requirements may be entered on the first NSCS card with subsequent cumulative NSCS cards having only entries for the remaining ultimate requirements.

NON-STANDARD CROSS-SECTION CARD		SERVICEABILITY				ULTIMATE		
		AREA OF BEAM OR BEAM SECTION (in^2 or mm^2)		Y_b OF BEAM OR BEAM SECTION (in or mm)	I_x OF BEAM OR BEAM SECTION (in^4 or $10^6 x\ mm^4$)	WIDTH OF COMPRESSION ZONE (in or mm)	MAX. DEPTH OF COMPRESSION ZONE (in or mm)	Y_b OF COMPRESSION ZONE (in or mm)
N S C S	10	20	30	40	50	60	70	80

Columns	Description
<1-4>	"NSCS" – Non-standard beam card identifier
<11-20>	Area of beam or beam section, in^2 or mm^2 (no default)
<31-40>	Distance from bottom of beam to centroid of beam or beam section, in. or mm (no default)
<41-50>	Moment of inertia of beam or beam section, in^4 or mm^4 * E6 (no default)
<51-60>	Width of ultimate bending moment compression zone of beam or beam section, in. or mm (no default)
<61-70>	Maximum depth of ultimate bending moment compression zone of beam or beam section, in. or mm (no default)
<71-80>	Distance from bottom of beam to centroid of compression zone of beam or beam section, in. or mm (no default)

Example:

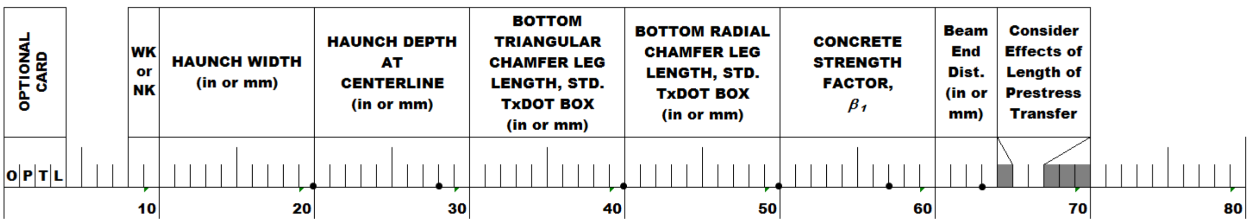
Definition of a 6T22 beam as a non-standard cross section

```
NSCS          706.0              14.74    26395.0      70.50     6.00       19.00
NSCS                                                   17.50    16.00        8.00
```

OPTL – Optional Input Description

(non-cumulative, no carry-over)

Information regarding shear key option, haunch dimensions, Box beam chamfer dimensions, concrete strength factor for equivalent rectangular stress block, beam end distance, and input for consideration of the effects of the length of transfer of prestress may be input with the OPTL card.



Columns	**Description** (defaults are shown in parentheses)
<1-4>	"OPTL" – Optional card identifier
<9-10>	Shear key indicator WK {With Key} or NK {No Key}. (WK for standard Box; not applicable for standard I, TxGirder, and non-standard beams; NK for U, Slab, Decked Slab, Double-T and X beams)
<11-20>	Haunch width, in. or mm (0.0)
<21-30>	Haunch depth at centerline of beam, in. or mm (0.0)
<31-40>	Leg length of bottom triangular chamfer in standard TxDOT Box beam, in. or mm (0.0 for standard TxDOT Box beam; not applicable for all other standard beams and non-standard beams; also not applicable for 40" TxDOT Box beams having length greater than 100' and standard AASHTO Box beams, since these already have chamfers included)
<41-50>	Leg length of bottom radial chamfer in standard TxDOT Box beam, in. or mm (0.0 for standard TxDOT Box beam; not applicable for all other standard beams and non-standard beams; also not applicable for 40" TxDOT Box beam having length greater that 100' and standard AASHTO Box beams, since these already have chamfers included)
<51-60>	Concrete strength factor, $ß_1$, for moment capacity calculations (calculated in accordance with the appropriate AASHTO specifications for the appropriate concrete strength. For flanged sections a weighted $ß_1$ value is calculated based on area of different concrete strengths within the compressive stress block.)
<61-64>	Distance from end of beam to centerline of bearing. (9" for standard TxGirders or X beams; 5.5" for standard Slab Beam; 8" for standard Decked-slab beam; 6.5" for all other standard and non-standard beams).
<66-67>	Enter '1' in column 67 or enter a non-standard number of strand diameters

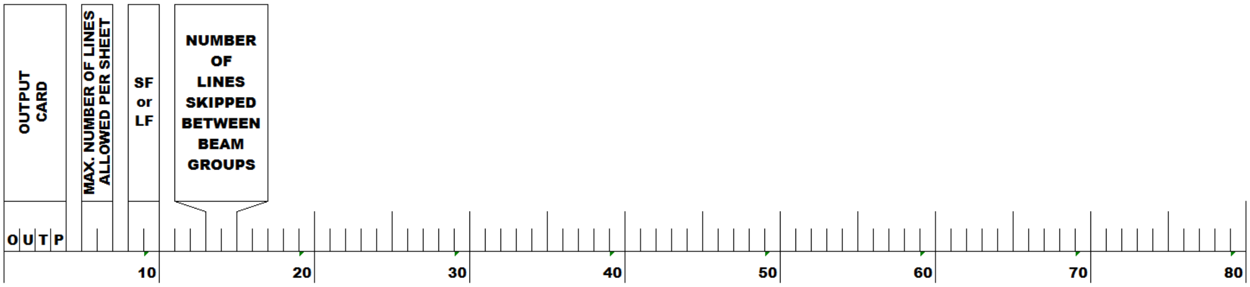
over which transfer of prestress is assumed to occur to considered the effects of the length of prestress transfer. If ‘1’ is entered, the transfer length specified in the selected design specifications will be used. If no ‘OPTL’ card exists for the beam or the value entered in column 67 is ‘0’ (and no value is entered in column 66) or blank, the effects of length of prestress transfer will not be considered. If a value between ‘2’ and ‘99’ is entered in 66 and/or 67, a transfer length equal to this user specified integer number of strand diameters times the diameter of the strand will be considered.

Note: If the calculated transfer length is less than or equal to the end distance (from beam physical end to bearing centerline), then the transfer length is reset equal to end distance + 0.01. For partially debonded strand beams, the calculated transfer length must be less than or equal to the debond-increment length, if it is longer a program error message will be generated and the program with terminate.

<u>OUTP – Output Options</u>

(non-cumulative, will carry-over)

Output options and number of lines skipped between beam groups in the beam summary and CAD file may be input with the OUTP card.



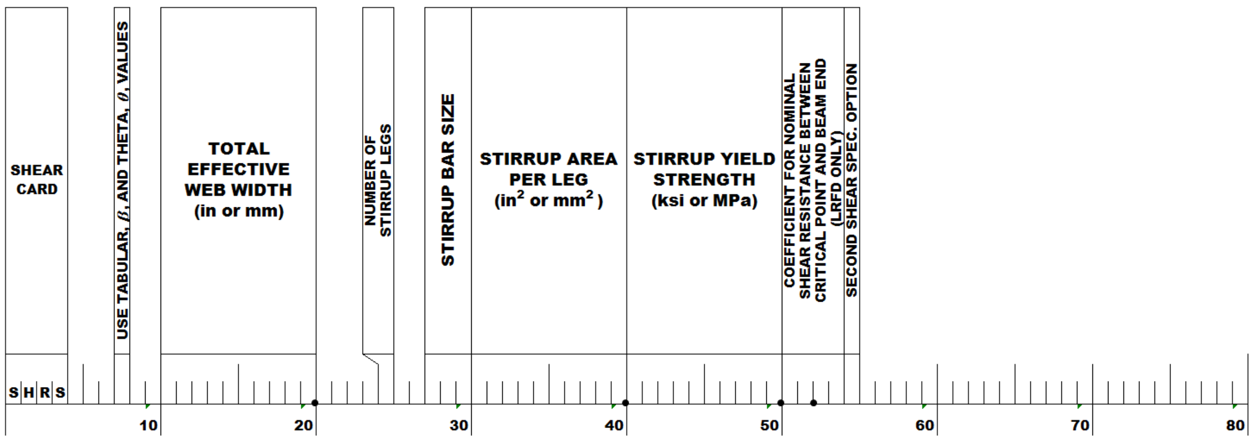
Columns	**Description** (defaults are shown in parentheses)
<1-4>	"OUTP" – Output card identifier
<6-7>	Maximum number of lines allowed on each sheet of output {enter 99 for no page breaks}. (56)
<9-10>	Output option SF {Short Form}, LF {Long Form}, or DB {Debug}. Long form includes moment, shear, stress, and prestress loss tables. Debug output is intended for developer use only and can be voluminous and slow down speed of program execution significantly. End users should not run *PSTRS14* in Debug output mode. No user support for this feature will be provided. (SF unless BEAMF card is used, in which case optional design output format is the default)
<14-15>	Number of lines to be skipped between beam groups in the Beam Summary and CAD file. (0)

<21-26>, <31-36>, <41-46>, <51-56>, 61-66, 71-76> If columns 9-10 are "DB", left-justified name(s) of subroutine(s) from which to print debug output {e.g. SHEAR}. End users should not run *PSTRS14* in Debug output mode. No subroutine names are disclosed and no user support for this feature is provided. This feature is strictly for program feature development and debugging. (no default)

SHRS – Shear Reinforcement and Specifications

(non-cumulative, will carry-over)

Effective web width, stirrup description and shear specification options may be input with the SHRS card.



Columns	**Description** (defaults are shown in parentheses)
<1-4>	"SHRS" – Shear card identifier
<10>	Enter 1 to use Beta, β, and Theta, θ, tables in LRFD shear calculations in lieu of AASHTO LRFD Equations 5.8.3.4.2-1 and 5.8.3.4.2-3, respectively. (0 or blank – i.e. use the equations)
<11-20>	Total effective web width for calculation of stirrup spacing, in. or mm. Since the web width is BEAM-specific and the SHRS card is a carry-over card, a message is printed when a value is entered in this field. (web width for standard I beam and TxGirder; 2 x width of one web for standard Box beam; smallest width of compression zone on NSCS card for non-standard beam; 10.0" or 254 mm for U beams; 17.50" or 444.5 mm for T22; 16.75" or 425.45 mm for T28; 15.75" or 400.05 mm for T36; 25.5" or 647.7 mm for HT22; 24.75" or 628.65 mm for HT28; 23.75" or 603.25 for HT36; 12" or 304.8 mm for Decked Slab beams; beam width for Slab beams)
<25>	Number of stirrup legs (2; 4 for Double-T beams)
<28-30>	Stirrup bar size: The size defaults to a value based upon the entry in cols. 31-40. (#4 for standard I beam, Box beam, Slab beam, Decked Slab beam, U beam, TxGirder and X beam sections; #3 for Double-T and non-standard beams)
<31-40>	Stirrup area per leg, in^2 or mm^2. The area defaults to a value based upon the entry in col. 30. A value in this field overrides the stirrup size in col. 30. (0.196 or 126.5 for standard I beam, Box beam, Slab beam, Decked Slab beam, U beam, TxGirder and X beam sections; 0.110 or 70.97 for Double-T and non-standard beams)

<41-50> Yield strength of stirrup, ksi or MPa (60. or 420.)

<51-54> Coefficient for nominal shear resistance between critical point and beam end for LRFD design only. (0.18)

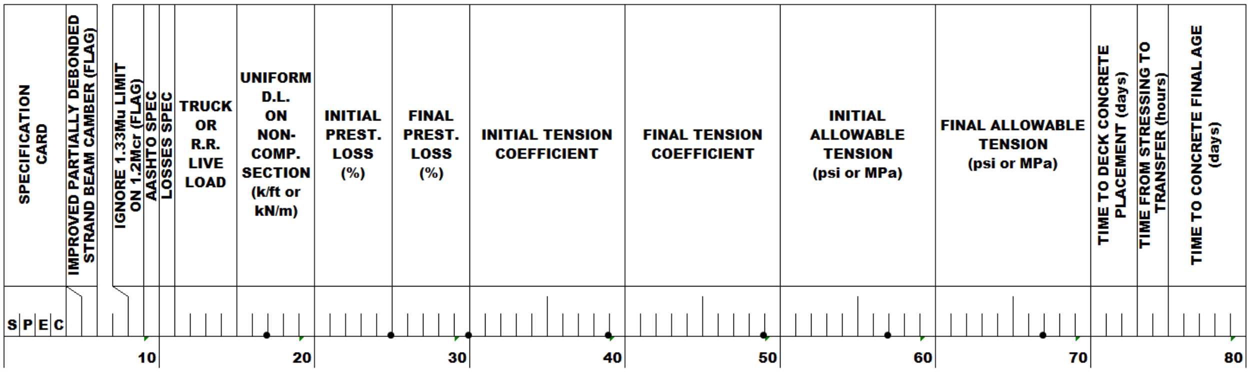
<55> Additional shear specification options. Enter one of the following numbers ("1" when primary specification is AASHTO LRFD Specifications and "2" when primary specification is AASHTO Standard Specifications):

"1" AASHTO 1989
"2" ACI 1989
"3" AREMA

SPEC – Miscellaneous Design Parameters

(non-cumulative, no carry-over)

Certain design parameters that are usually tied to specifications may be input with the SPEC card. Defaults are shown in parentheses.



Columns	Description (defaults are shown in parentheses)
<1-4>	"SPEC" – Specification card identifier
<6>	Use improved camber calculations for partially debonded strand beams {flag}. '0' or blank to use the traditional method for calculating the initial elastic camber portion of the camber estimation of partially debond strand beams, '1' to use the improved "statically correct" method for this initial elastic camber. (0)
<9>	Ignore 1.33M_u Limit {flag}. Ignore 1.33M_u upper limit on 1.2M_{cr} (or on M_{cr} for LRFD 2012 Spec). '0' or blank to consider the limit, '1' to ignore the limit. **Note:** This field has been relocated from column 78 in previous versions. (0)
<10>	Design/Analyze according to AASHTO Spec., '0' for 2002 (same as 1995) AASHTO Standard Spec., '1' for 1994 AASHTO Standard Spec., '5' for 3rd Edition (2004) thru 4th Edition (2007) AASHTO LRFD Spec., '9' for 5th Edition (2009) thru 2010 Interim AASHTO LRFD Spec., or 'A' for 6th Edition (2012) AASHTO LRFD Spec. ('0' - 2002 AASHTO Standard Spec.)
<11>	Methodologies for estimating prestress losses. '0' for using the 1994 AASHTO Standard Spec. losses, '4' for using the 2004 AASHTO LRFD Spec. losses, '7' for using the 4th Edition (2007) thru 6th Edition (2012) AASHTO LRFD Spec. losses, or 'A' for using the TxDOT 2012 (Project 0-6794 recommended methodology) losses. If a non-standard beam section is specified along with the prestress losses spec "7", the user must input the volume-to-surface ratio of the non-standard beam on the BEAM card to get full and "correct" output. ('0' - 1994 AASHTO Standard Spec. losses, if design spec. is AASHTO Standard Spec.; '4' - 2004 AASHTO LRFD Spec. losses)

<12-15> AASHTO Standard Truck designation or AREMA Railroad designation, left justified. Allowable entries for AASHTO Standard Truck are H15, H20, HS20, or HL93. Allowable entries for AREMA Railroad are E50, E72, E80, etc., in the range E50-E150 (HS20 for AASHTO Standard Spec., HL93 for LRFD Spec., and Non-Standard if LVEU or LVEC cards are input)

<16-20> Uniform dead load on non-composite section, klf or kN/m (no default)

<21-25> Initial prestress loss, percent. This field is used to enter a fixed value for the initial loss of prestress. An entry is also required in cols. 26-30. Not allowed for input when using AASHTO 2007 Spec. or TxDOT 2012 Spec. losses. (no default)

<26-30> Final prestress loss, percent. This field is used to enter a fixed value for the final loss of prestress. An entry is also required in cols. 21-25. The final prestress loss must be greater than or equal to the initial prestress loss. Not allowed for input when using AASHTO 2007 Spec. or TxDOT 2012 Spec. losses. (no default)

<31-40> Multiplier to determine the initial tensile stress allowed. This allowable stress is determined by multiplying this number by the square root of f'_{ci} (psi) for other than AASHTO 2012 design spec., or the square root of f'_{ci} (ksi) for AASHTO 2012 design spec. (7.5 for other than AASHTO 2012 design spec; 0.24 for AASHTO 2012 design spec.)

<41-50> Multiplier to determine the final bottom fiber tensile stress allowed. This allowable stress is determined by multiplying the square root of f'_c (psi) by this number. (6.0 for AASHTO 2004 thru 2010 design spec.; 0.19 for AASHTO 2012 design specs; 0.0 for AREMA design spec.)

<51-60> Initial allowable tensile stress, psi or MPa. A negative sign {-} must be entered for the tensile stress. The maximum initial tensile stress is limited to the value entered in this field. When this field is used, the multiplier field in cols. 31-40 cannot be used; the default initial tensile stress multiplier is used to determine the concrete release strength. (no default)

<61-70> Final allowable bottom fiber tensile stress, psi or MPa. Negative sign {-} must be input for tensile stress. The maximum final bottom fiber tensile stress is limited to the value entered in this field. When this field is used, the multiplier field in cols. 41-50 cannot be used; the default final tensile stress multiplier is used to determine the final concrete strength. (no default)

<71-73> Age of concrete when deck is placed. Time estimated in days. (120)

<74-75> Age of concrete when load is initially applied. Time estimated in hours from stressing to transfer. (24 hours)

<76-80> Days to concrete final age. (2000)

Note: Starting with version 5.0, the program will always check longitudinal reinforcement requirements. The option for not checking LRFD longitudinal reinforcement that had been available using a flag in column 80 has been removed.

STPR & LOCR – Specified Prestressing Strand Pattern

(analysis only)
(cumulative, no carry-over)

The number of strands per row and the distance from bottom of beam to centroid of each row at the centerline of the span and at the ends of the beam may be input with the STPR/LOCR cards. A maximum of three sets of STPR/LOCR cards (14 rows per card, for a maximum of 35 rows) are allowed per BEAM card.

The STPR/LOCR cards may be used to enter draped strand patterns, straight strand pattern with no debonding and centerline straight strand pattern when used with DBPR/LOCR cards.

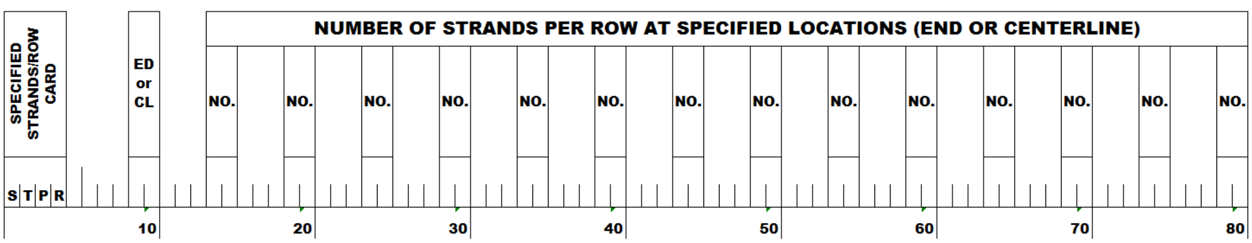
The strand pattern defined by STPR/LOCR cards must not have crossing stands. If any row of strands is draped all rows above that row must also be draped, except for one to two rows of straight strands placed in the upper portion of the beam for controlling handling stresses and/or beam camber.

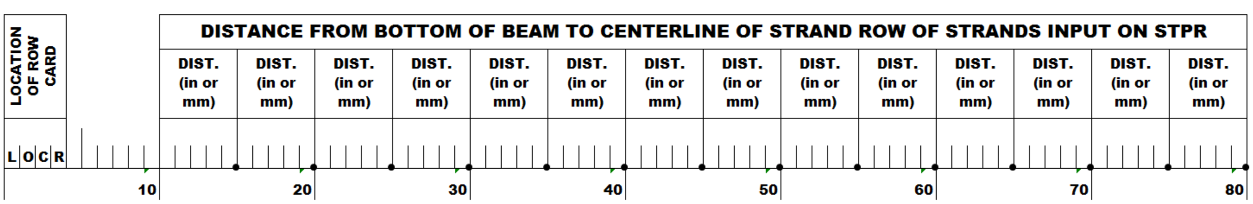
The STPR card with "CL", for centerline, in columns 9-10 must be input before the STPR card with "ED", for end, in columns 9-10.

For a standard Box beam having a straight strand pattern with no debonding, a STRD card with "ND" in cols. 69-70 must precede the STPR/LOCR cards. (This is required because the default for a standard Box beam is "WD.")

Either the STPR/LOCR card set or the CGSL card is required for any analysis.

A fatal error occurs if there is no entry in cols. 9-10 of the STPR card.





Columns	Description (defaults are shown in parentheses)
<1-4>	"STPR" – Specified strands per row card identifier
<9-10>	Section location "CL" {Center Line} or "ED" {End} (entry required)
<14-15>,…	Specified number of strands per row. Number of strands per row may be

entered in fourteen successive 2-column fields, beginning in cols. 14-15 and ending in cols. 79-80. Blank fields of input are not allowed; the program reads a blank field as the end of input data for that card. (no default)

<19-20>,<24-25>,<29-30>,... ,<79-80> Same as <14-15> above.

Each STPR card must be immediately followed by a corresponding LOCR card.

Columns	**Description**
<1-4>	"LOCR" – Row location card identifier
<11-15>,...	Distance from bottom of beam to centroid of strand row, in or mm. Distance to each row for the number of strands entered on the preceding STPR card must be entered in the successive 5-column fields, beginning in cols. 11-15 and ending in cols. 76-80. An entry must be made on this card for each field on the STPR card. The entry must be made in the order of increasing distance. Blank fields of input are not allowed; the program reads a blank field as the end of input data for that card. (no default)

<16-20>, <21-25>, <26-30>,... , <76-80> Same as <11-15> above.

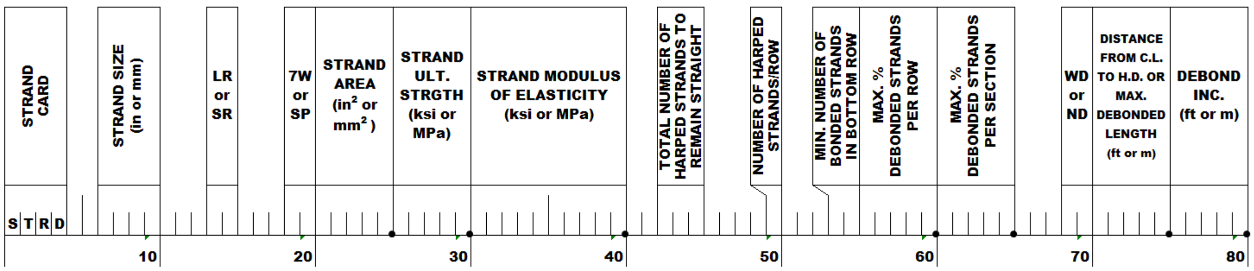
Notes for STPR Card:

1. Strand rows located at CL must also be specified at ED. If a strand row at CL is harped and that row does not reach ED, the number of strand per row at ED must be specified as 0 and must not be blank.
2. No crossing or grouping of strands are allowed.

STRD – Prestressing Strands

(non-cumulative, will carry-over)

Prestressed strand properties, harped strand options, debonding options and distance from midspan to hold-down may be input with the STRD card. The STRD card controls over other related input. For example, for a standard I-beam or non-standard beam, the STRD card with “WD” in cols. 69-70 must be entered before DBPR/LOCR cards are entered. Table 1 of**Error! Reference source not found. Appendix A – Table 1 and Figure 1 thru Figure 19** gives the standard strand types available in *PSTRS14*. A detailed explanation of the input options for strand size, type, area, and strength is given in the input descriptions below.



Columns	**Description** (defaults are shown in parentheses)
<1-4>	“STRD” – Prestressing strand card identifier
<7-10>	Size of strand, left justified, in. or mm. A standard strand size, as shown in **Error! Reference source not found.**of Table 1 of **Appendix A – Table 1 and Figure 1 thru Figure 19**, or a non-standard strand size may be entered. Allowable entries are 1/4, 5/16, 3/8, 7/16, 1/2, 9/16, .600, and .700. A non-standard strand size entry must be in decimal form. A standard strand area entered in cols. 21-25 overrides the strand size entered in this field. (default is dependent on user input; 1/2 if no entry in cols. 21-25)
<14-15>	Type indicator LR {Low Relaxation} or SR {Stress-Relieved} (LR)
<19-20>	Type indicator 7W {7-Wire} or SP {special} (7W)
<21-25>	Area of strand, in^2 or mm^2. A standard strand area, as shown in Table 1 of**Error! Reference source not found.** Appendix A – Table 1 and Figure 1 thru Figure 19, in this field overrides the strand size in cols. 7-10. (default is dependent on user input; 0.153 or 98.71 if no entry in cols. 7-10, 19-20 and 26-30)
<26-30>	Ultimate strength of strand, ksi or MPa (270. or 1860.)
<31-40>	Modulus of elasticity of strand, ksi or MPa (28000. or 193053. for Standard Specifications, 28500. or 196501. for LRFD)
<43-45>	Total number of harped strands to remain straight. Input may be an integer multiple of the total number of harped strands per row or may be “ALL”. (0 for standard I beam, TxGirder, and non-standard beams, 4 for Double-T and 0 for Double-HT beams; not applicable for standard Box, U, Slab,

Decked Slab, and X beams)

Enter “ALL” for beams with straight strands and no debonding allowed, along with “ND” in cols. 69-70.

<50> Total number of harped strands per row (2 for standard I beams, TxGirder, and non-standard beams, 4 for Double-T beams, 8 for Double-HT beams; not applicable for standard Box, U, Slab, Decked Slab, and X beams)

<54-55> Minimum number of strands to remain bonded in bottom row, for debonding option (4 for standard Double-T and Double-HT beams; 6 if even number of strands and 7 if odd number of strands, for standard I beam, Box beam, Slab beam, Decked Slab beam, U beam, TxGirder and X beam sections, and non-standard beams). For non-standard beams ensure that the default or specified value will result in a symmetrical bonded strand pattern.

<56-60> Maximum percentage of debonded strands per row (37.5% for debonded standard I beams, standard TxGirders, and non-standard beams, 50.0% for debonded Double-T and Double-HT beams, and 75.0% for standard Box, Slab, Decked Slab, U beams and X beams).

<61-65> Maximum percentage of debonded strands per section (25.0% for debonded standard I beams, standard TxGirder, and non-standard beams, 50.0% for debonded Double-T and Double-HT beams, and 75.0% for standard Box, Slab, Decked Slab, U beams and X beams).

<69-70> Debonding option WD (with debonding) or ND (no debonding) (ND for standard I beams, Double-T beams, TxGirders, and non-standard beams; WD for standard Box beams, Slab beams, Decked Slab beams, U beams and X beams).

Enter “WD” for standard I, Double-T, TxGirder, and non-standard beams with straight strands and debonding allowed.

Enter “ND," along with "ALL" in cols. 43-45, for beams with straight strands and no debonding allowed.

<71-75> Distance from midspan to hold-down point for draping option, ft or m (greater of 5.00 ft or 1.524 m, or 1/20th span length), or maximum debonded length for debonding option, ft or m (lesser of half span minus internally calculated maximum development length, 10 x debonding increment, 0.2 span length, or 15.00 ft or 4.572 m)

To set the hold-down point centerline, input a 0.001 since 0.0 is not valid for this field.

<76-80> Debonding increment, ft or m (3.00 or 0.914).

INPUT OPTIONS FOR STRAND SIZE, TYPE, AREA AND STRENGTH

The strand “Size”, “Type” (7W or SP), “Area”, and “Ultimate Strength” are all interrelated. **Error! Reference source not found.** Table 1 in Appendix A – Table 1 and Figure 1 thru Figure 19 shows standard strands that are available in the *PSTRS14* internal library. Accessing these standard strands with a minimum amount of input and entering non-standard strands are described in this section.

Twelve standard seven-wire (7W) strands and one standard special (SP) strand are stored in the *PSTRS14* strand library. Seven-wire is the default strand type used by the program. This may be changed to special by inputting “SP” in columns 19-20 of the STRD card.

The “Ultimate Strength” default is “270”. The other “Ultimate Strength” available is “250” and must be input by the user. The “Ultimate Strength” default or input value will determine the default values of “Size” and “Area”. The following list shows the default values available, depending upon which “Type” and “Strength” are used.

	ULTIMATE	**DEFAULT**	
TYPE	**STRENGTH**	**SIZE**	**AREA**
7W *	270 *	1/2	0.153
7W *	250	1/2	0.144
SP	270 *	1/2	0.167
7W *	270 *	0.6	0.217
7W *	270 *	0.7	0.294

* Default values not required to be input.

The default area and default size are interrelated. They depend on the type and ultimate strength. The input area will override any input in the size field, or will set the size default, if no size is entered. The input size will set the default for the area if no area is entered. The following list shows a few options that are available to minimize the amount of input by using defaults.

ENTERED VARIABLES				**DEFAULTS AND RESULTS**			
SIZE	**TYPE**	**AREA**	**STRENGTH**	**SIZE**	**TYPE**	**AREA**	**STRENGTH**
1/2 *	7W *	0.153 *	270 *	1/2	7W	0.153	270
	7W *	0.036	250	1/4	7W	0.036	250
7/16*	7W *	0.085	270 *	3/8	7W	0.085	270
5/16	7W *		250	5/16	7W	0.058	250
1/2 *	SP	0.167 *	270 *	1/2	SP	0.167	270

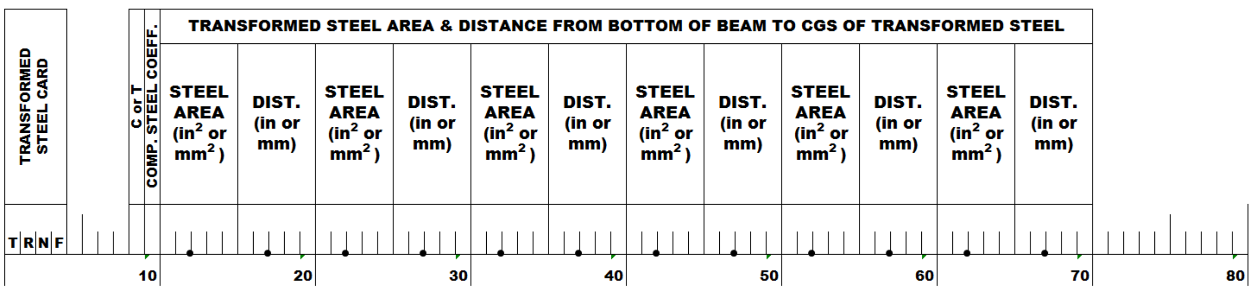
* Default values not required to be input.

TRNF – Transformed Steel Description

(non-cumulative for compression steel, no carry-over)

Transformed compression or tension steel may be input with the TRNF card. One TRNF card (maximum of 6 entries for steel area and 6 entries for distance from bottom of beam) per BEAM card is allowed for compression steel input. A maximum of two TRNF cards per BEAM card is allowed for tension steel. Therefore, a maximum of three TRNF cards is allowed per BEAM card.

A fatal error occurs if this card is used without an entry in column 9 (transformed steel type indicator).



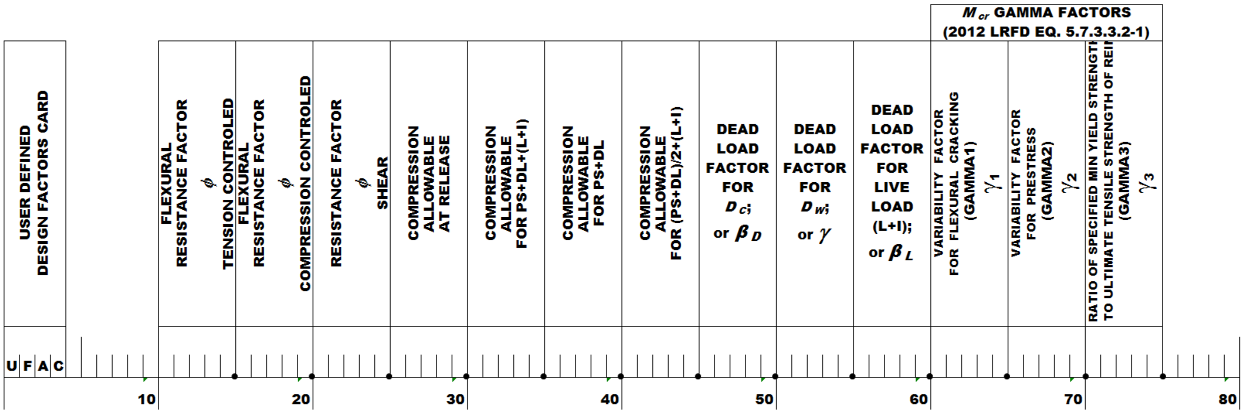
Columns	**Description** (defaults are shown in parentheses)
<1-4>	"TRNF" – Transformed steel card identifier
<9>	Transformed steel type indicator C {Compression steel} or T {Tension steel} (entry required)
<10>	Compression steel coefficient (default = 1)
<11-15>	Steel area, in^2 or mm^2 (no default)
<16-20>	Distance from bottom of beam to centroid of steel, in. or mm (no default)

<21-25>,<31-35>,<41-45>,<51-55>,<61-65> same as <11-15> above.

<26-30>,<36-40>,<46-50>,<56-60>,<66-70> same as <16-20> above.

UFAC – User Defined Design Factors

(non-cumulative, no carry-over)



Columns	**Description**
<1-4>	"UFAC" - User defined design factors card identifier
<11-15>	Resistance factor ϕ when tension controls (1.0 typical; 0.95 for railroad loadings)
<16-20>	Resistance factor ϕ when compression controls (0.75 for 2007 thru 2012 LRFD Specs only; not applicable for other specs)
<21-25>	Resistance factor ϕ for shear (0.9)
<26-30>	Initial (at release) allowable compression coefficient (0.65)
<31-35>	Final allowable compression coefficient for load combination PS+DL+(L+I) (0.6 for LRFD Specs; 0.4 for Standard Specs)
<36-40>	Final allowable compression coefficient for load combination PS+DL (0.45 for LRFD Spec; 0.4 for 95 Standard Spec; not applicable for 94 Standard Spec)
<41-45>	Final allowable compression coefficient for load combination (PS+DL)/2+(L+I) (0.4 for 95 Standard Spec and LRFD 2007 Spec; not applicable for 94 Standard Spec and 2009 thru 2012 LRFD Specs)
<46-50>	Load Factor for dead load DC or β_D coefficient (DC=1.25 for LRFD Specs; β_D=1.0 for Standard Specs; 1.4 for AREMA Spec)
<51-55>	Dead Load Factor DW or Load Factor γ (γ=1.3 for Standard Spec; DW=1.5 for LRFD specs; not applicable for other specs)
<56-60>	Live Load Factor or β_L coefficient (1.75 for LRFD specs; 5/3 for Standard specs; 7/3 for AREMA Spec.)
<61-65>	Flexural-cracking variability factor for input into LRFD 2012 Spec Eq. 5.7.3.3.2-1, M_{cr} **(1.6)**
<66-70>	Prestress variability factor for input into LRFD 2012 Spec Eq. 5.7.3.3.2-1, M_{cr} (1.1)

<71-75> Ratio of specified minimum yield strength to ultimate tensile strength of the reinforcement (1.0)

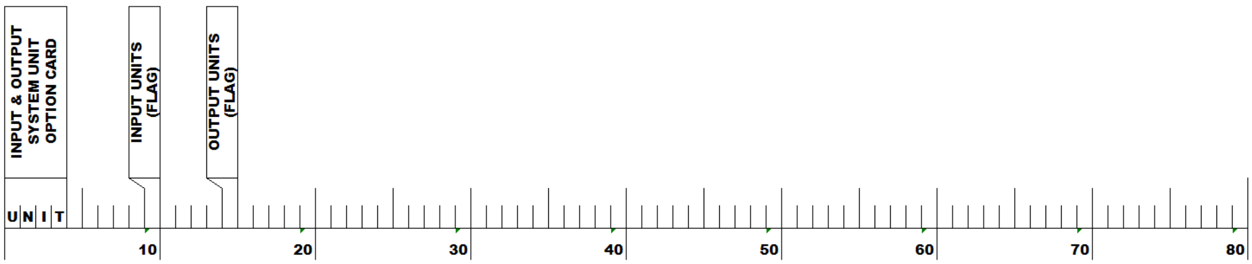
Note: Load factors are for the default or user chosen specification (the primary specification), not for the secondary specification that is used for comparison of shear computation.

UNIT – Input & Output System Unit Option

(non-cumulative, will carry-over)

This card specifies whether input and output units are in English or metric. This card may be omitted if input and output both use English units. If used, it should immediately follow the first PROB card.

Defaults are shown in parentheses.

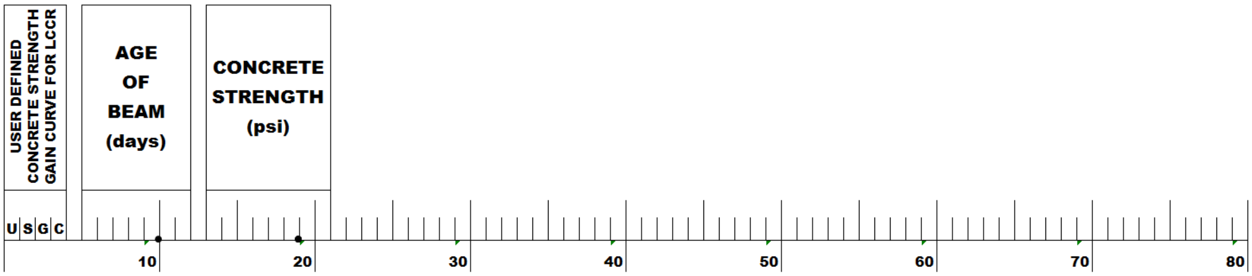


Columns	Description
<1-4>	“UNIT” – Input and output unit card identifier
<10>	Input units; E or e for English, M or m for metric. (E)
<15>	Output units; E or e for English, M or m for metric. (E)

USGC – User Defined Concrete Strength Gain Curve for Life Cycle Camber

(non-cumulative, no carry-over)

This card can be used to override the default strength gain curve (concrete strength vs. time) used to calculate the corresponding modulus of elasticity gain curve used in the Life Cycle Camber Report (LCCR) analysis.



Columns	**Description**
<1-4>	"USGC" – User Defined Concrete Strength Gain Curve card identifier.
<6-12>	Age of the beam, days. (no default)
<14-21>	Concrete strength. (no default)

Note: Metric units not supported for input for this command.

References

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2. American Association of State Highway and Transportation Officials (AASHTO), Standard Specifications for Highway Bridges, 15th Edition, Interim Revisions 1994 and 1995, and 17th Edition – 2002.
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5. American Association of State Highway and Transportation Officials (AASHTO), Load and Resistance Factor Design (LRFD) Bridge Design Specifications, 5th Edition (2009) thru 2010 Interim.
6. American Association of State Highway and Transportation Officials (AASHTO), Load and Resistance Factor Design (LRFD) Bridge Design Specifications, 6th Edition (2012).
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    URL: http://www.utexas.edu/research/ctr/pdf_reports/0_5197_4.pdf (accessed February 22, 2016)
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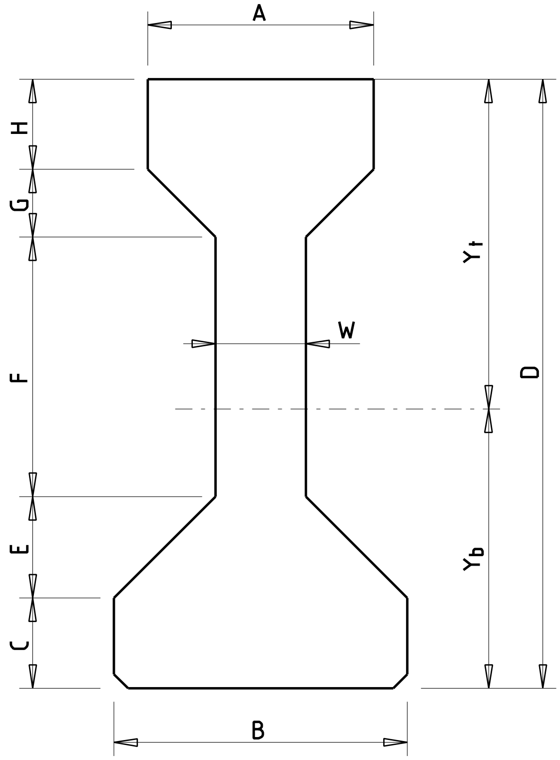
    URL https://fsel.engr.utexas.edu/pdfs/381-1.pdf (accessed February 22, 2016)

15. Walton, S. and Bradberry, T. E., "Comparison of Methods of Estimating Prestress Losses for Bridge Girders," ***Proceedings***, Ameican Society of Civil Engineers, Texas Section Fall Meeting, Sept 29-Aug 2, 2004, Houston, Texas.
URL: http://ftp.dot.state.tx.us/pub/txdot-info/library/pubs/bus/bridge/girder_comparison.pdf (accessed February 22, 2016)
16. Texas Department of Transportation (TxDOT), Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges, 2004 Edition, Adopted by the Texas Department of Transportation, June 1, 2004

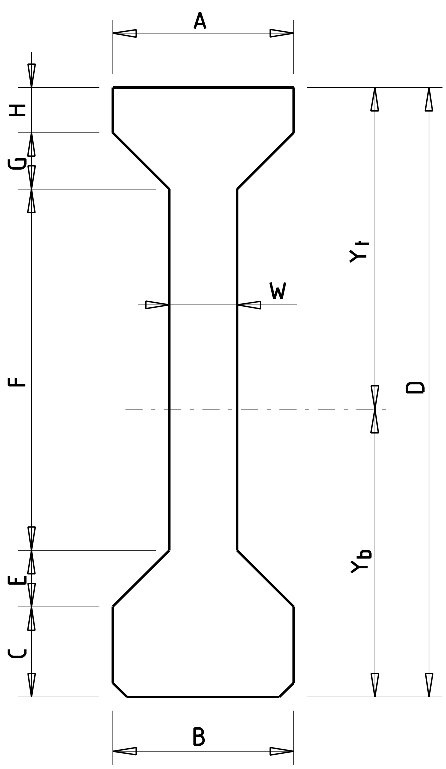
Appendix A – Table 1 and Figure 1 thru Figure 19

Table 2 – Standard Strand Table

Nominal Diameter (in)	Nominal Area (in^2)
GRADE 250, SEVEN-WIRE	
1/4	0.036
5/ 16	0.058
3/8	0.080
7/16	0.108
1/2	0.144
.600	0.216
GRADE 270, SEVEN-WIRE	
3/8	0.085
7/16	0.115
1/2	0.153
1/2 special	0.167
9/16	0.192
.600	0.217
.700	0.294



Dimension/ Property		BEAM TYPE			
		A	B	C	IV
A	in	12	12	14	20
B	in	16	18	22	26
C	in	5	6	7	8
D	in	28	34	40	54
E	in	5	5 3/4	7 1/2	9
F	in	11	14	16	23
G	in	3	2 3/4	3 1/2	6
H	in	4	5 1/2	6	8
W	in	6	6 1/2	7	8
Yt	in	15.39	19.07	22.91	29.25
Yb	in	12.61	14.93	17.09	24.75
Area	in^2	275.4	360.3	494.9	788.4
I	in^4	22,658	43,177	82,602	260,403
Wt/Lf	lbs	287	375	516	821



Dimension/ Property		BEAM TYPE	
		54	72
A	in	16	22
B	in	16	22
C	in	8	11
D	in	54	72
E	in	5	7 1/2
F	in	30	40 1/2
G	in	5	7 1/2
H	in	4	5 1/2
W	in	6	7
Yt	in	28.47	38.27
Yb	in	25.53	33.73
Area	in^2	493.4	863.4
I	in^4	164,022	532,060
Wt/Lf	lbs	514	899

Figure 1 – Standard I Beam Cross Section Properties

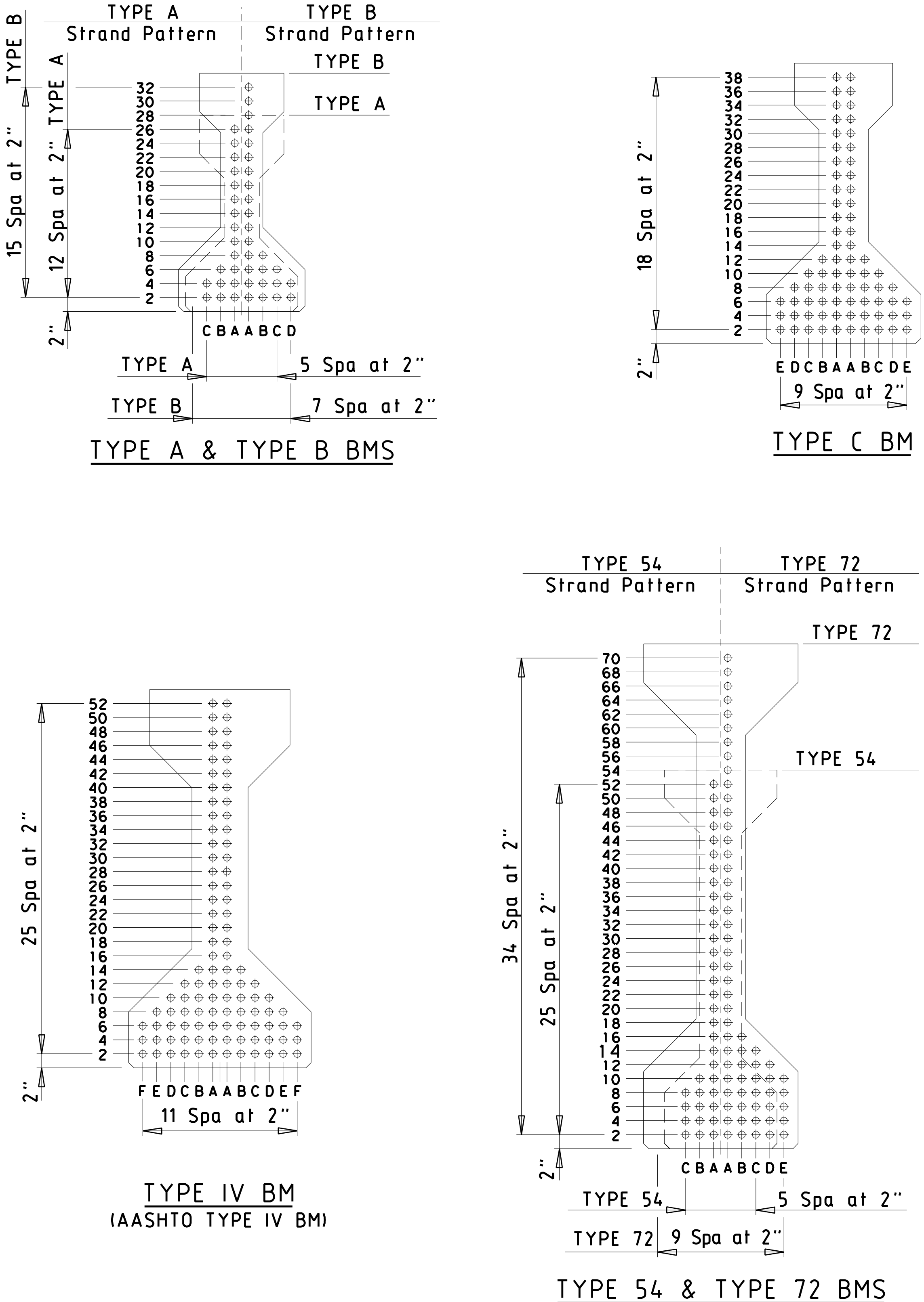
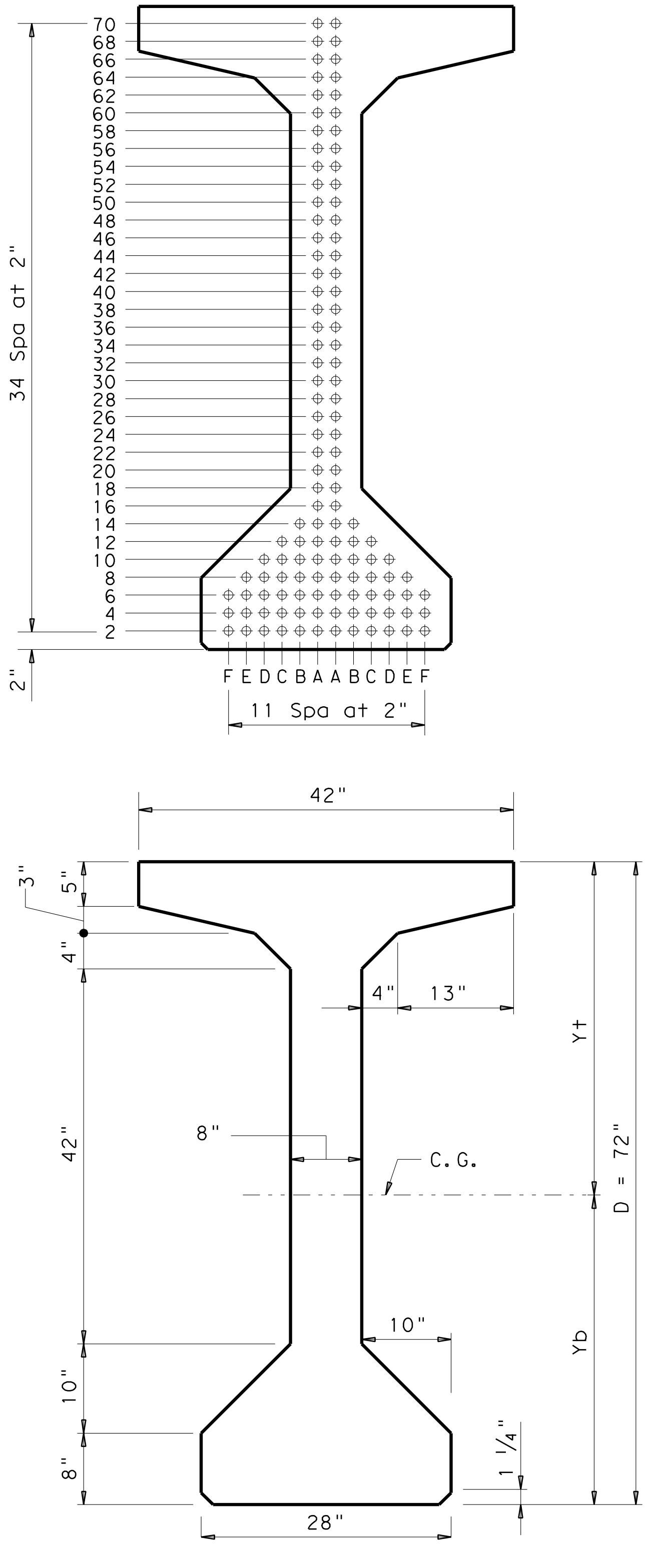
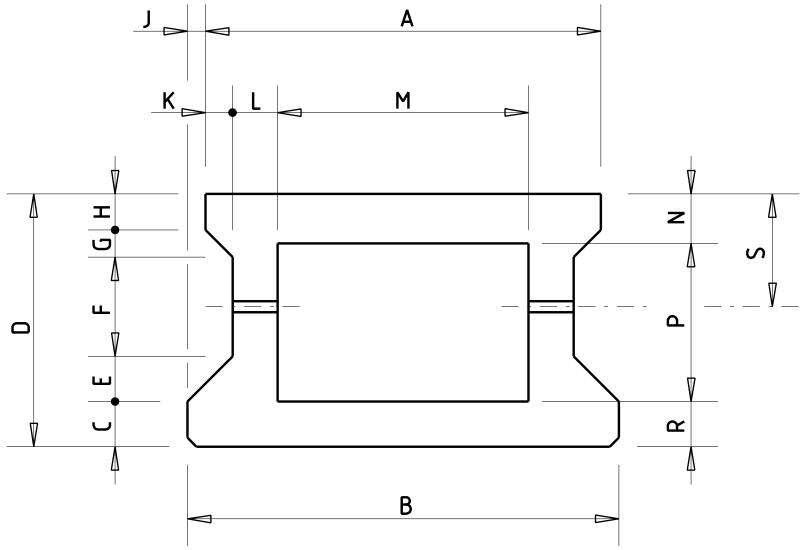


Figure 2 – Standard I Beam Strand Grids



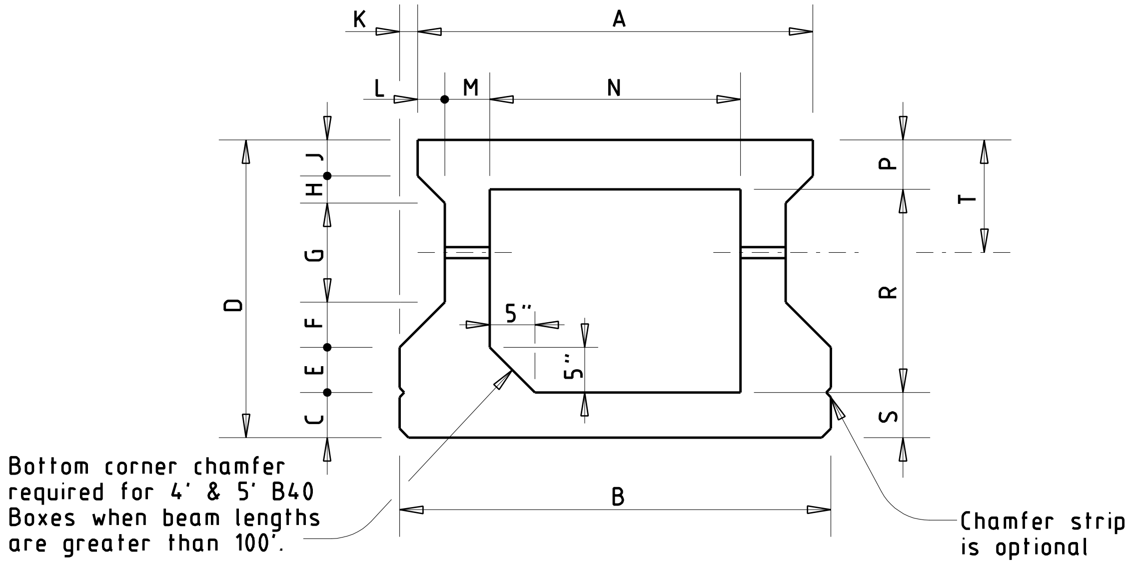
Yt in.	Yb in.	AREA in.²	I in.⁴	Weight plf
35.60	36.40	1,084.4	732,586	1,130

Figure 3 – Standard Type VI Beam Cross Section and Strand Grid



BEAM TYPE				
Variable	4B20	5B20	4B28	5B28
A	3'-7 3/4"	4'-7 3/4"	3'-7 3/4"	4'-7 3/4"
B	3'-11 3/4"	4'-11 3/4"	3'-11 3/4"	4'-11 3/4"
C	5"	5"	5"	5"
D	1'-8"	1'-8"	2'-4"	2'-4"
E	4"	4"	5"	5"
F	4"	4"	11"	11"
G	2"	2"	3"	3"
H	5"	5"	4"	4"
J	2"	2"	2"	2"
K	2"	2"	3"	3"
L	5"	5"	5"	5"
M	2'-5 3/4"	3'-5 3/4"	2'-3 3/4"	3'-3 3/4"
N	5 1/2"	5 1/2"	5 1/2"	5 1/2"
P	9 1/2"	9 1/2"	1'-5 1/2"	1'-5 1/2"
R	5"	5"	5"	5"
S	9"	9"	1'-0 1/2"	1'-0 1/2"
Y_{top} (in)	10.19	10.12	14.38	14.26
Y_{bott} (in)	9.81	9.88	13.62	13.74
Area (in^2)	591.8	717.8	678.8	804.8
I (in^4)	28,086	35,234	68,745	85,370
Wt/Lf (lbs)	616	748	707	838

Figure 4 – Standard Box Beam Cross Section Properties A (20" and 28" Depths)



BEAM TYPE						
Variable	4B34	5B34	4B40	5B40	4B40 (L > 100')	5B40 (L > 100')
A	3'-7 3/4"	4'-7 3/4"	3'-7 3/4"	4'-7 3/4"	3'-7 3/4"	4'-7 3/4"
B	3'-11 3/4"	4'-11 3/4"	3'-11 3/4"	4'-11 3/4"	3'-11 3/4"	4'-11 3/4"
C	6"	6"	1'-0"	1'-0"	1'-0"	1'-0"
D	2'-10"	2'-10"	3'-4"	3'-4"	3'-4"	3'-4"
E	5"	5"	5"	5"	5"	5"
F	5"	5"	5"	5"	5"	5"
G	11"	11"	11"	11"	11"	11"
H	3"	3"	3"	3"	3"	3"
J	4"	4"	4"	4"	4"	4"
K	2"	2"	2"	2"	2"	2"
L	3"	3"	3"	3"	3"	3"
M	5"	5"	5"	5"	5"	5"
N	2'-3 3/4"	3'-3 3/4"	2'-3 3/4"	3'-3 3/4"	2'-3 3/4"	3'-3 3/4"
P	5 1/2"	5 1/2"	5 1/2"	5 1/2"	5 1/2"	5 1/2"
R	1'-11 1/2"	1'-11 1/2"	2'-5 1/2"	2'-5 1/2"	2'-5 1/2"	2'-5 1/2"
S	5"	5"	5"	5"	5"	5"
T	1'-0 1/2"	1'-0 1/2"	1'-0 1/2"	1'-0 1/2"	1'-0 1/2"	1'-0 1/2"
Y_{top} (in)	17.92	17.72	21.31	21.07	21.63	21.36
Y_{bott} (in)	16.08	16.28	18.69	18.93	18.37	18.64
Area (in^2)	798.8	924.8	918.8	1044.8	943.8	1069.8
I (in^4)	115,655	142,161	176,607	215,300	180,159	219,007
Wt/Lf (lbs)	832	963	957	1088	983	1114

Figure 5 – Standard Box Beam Cross Section Properties B (34" and 40" Depths)

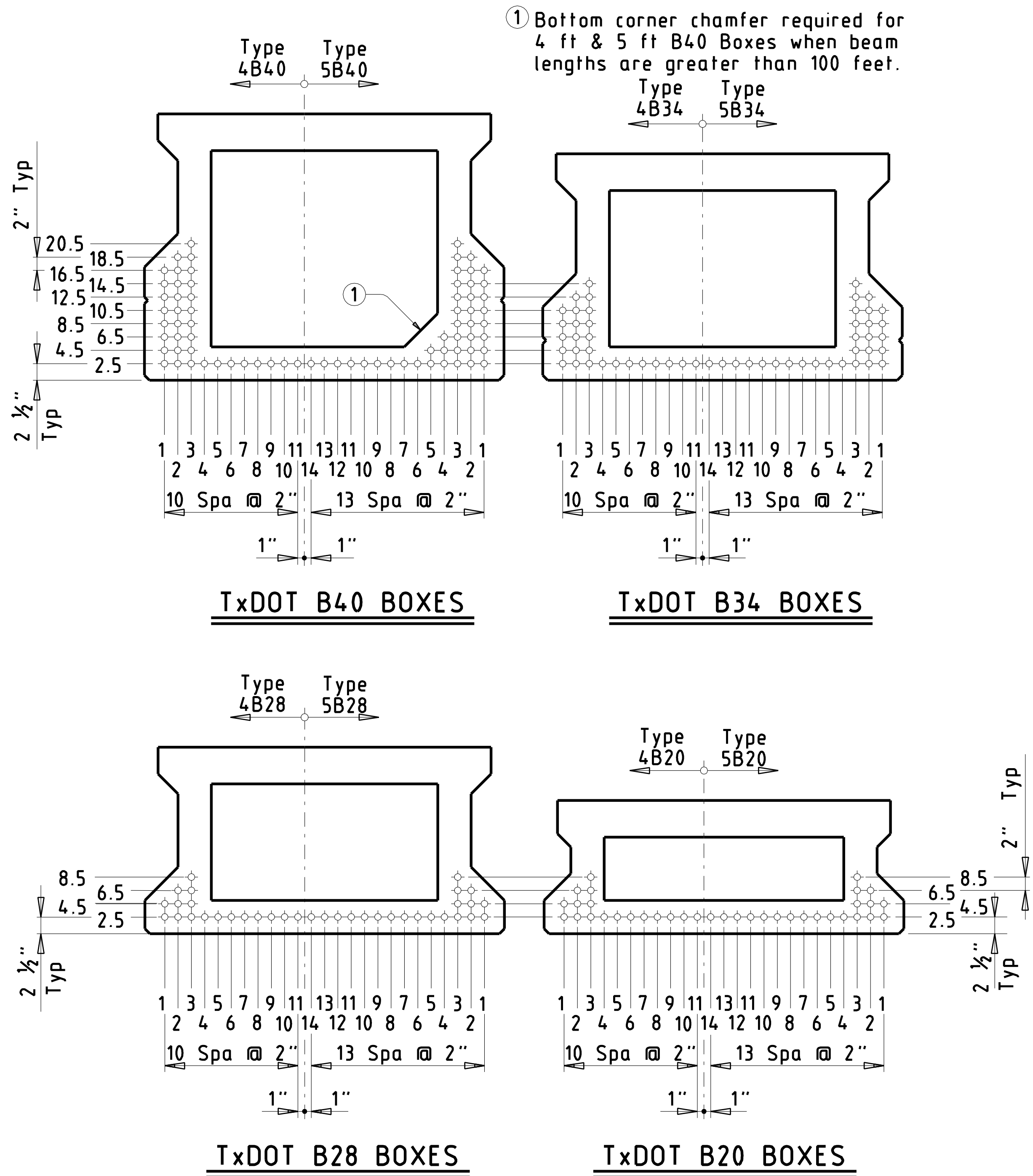


Figure 6 – Standard Box Beam Strand Grids

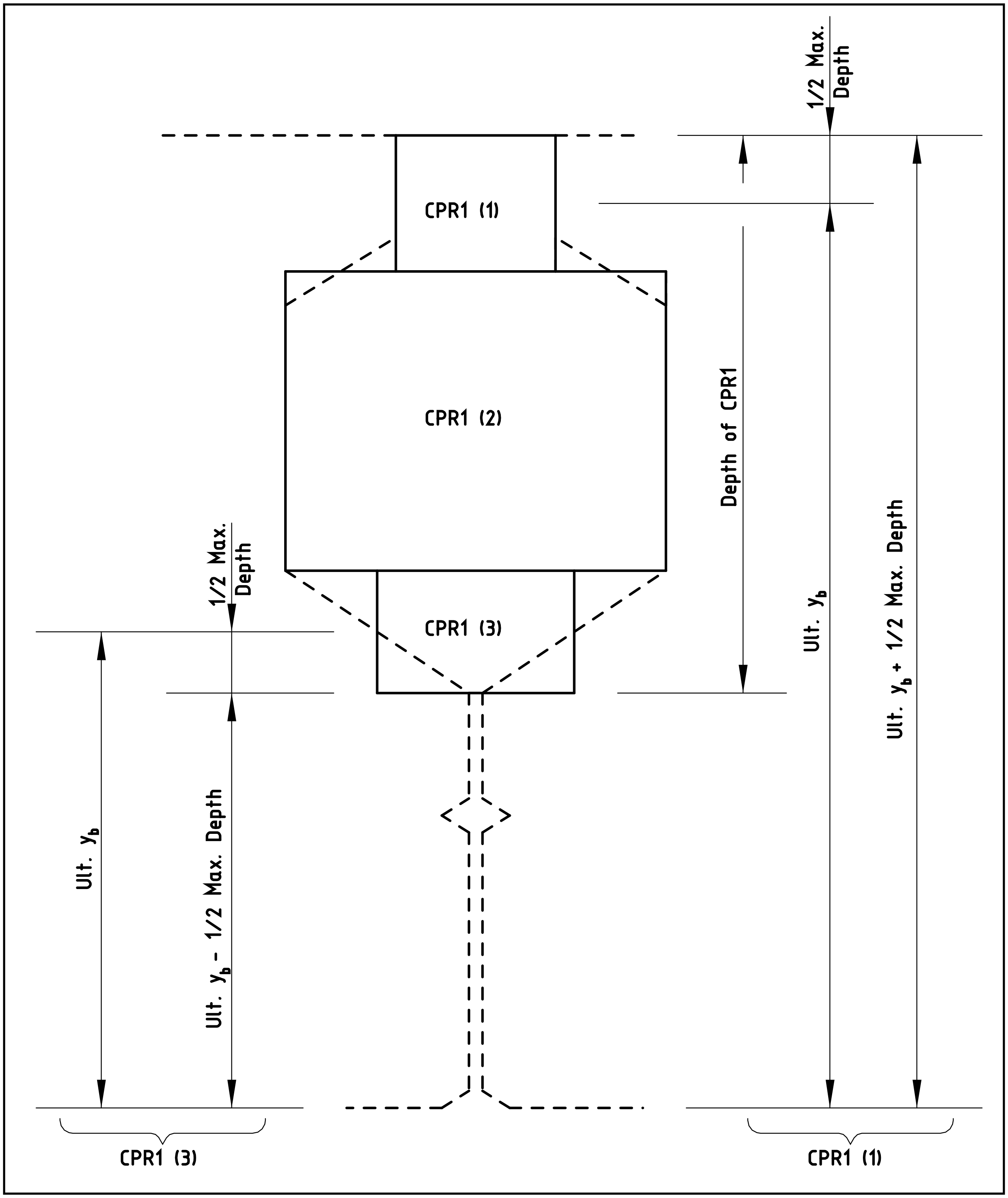
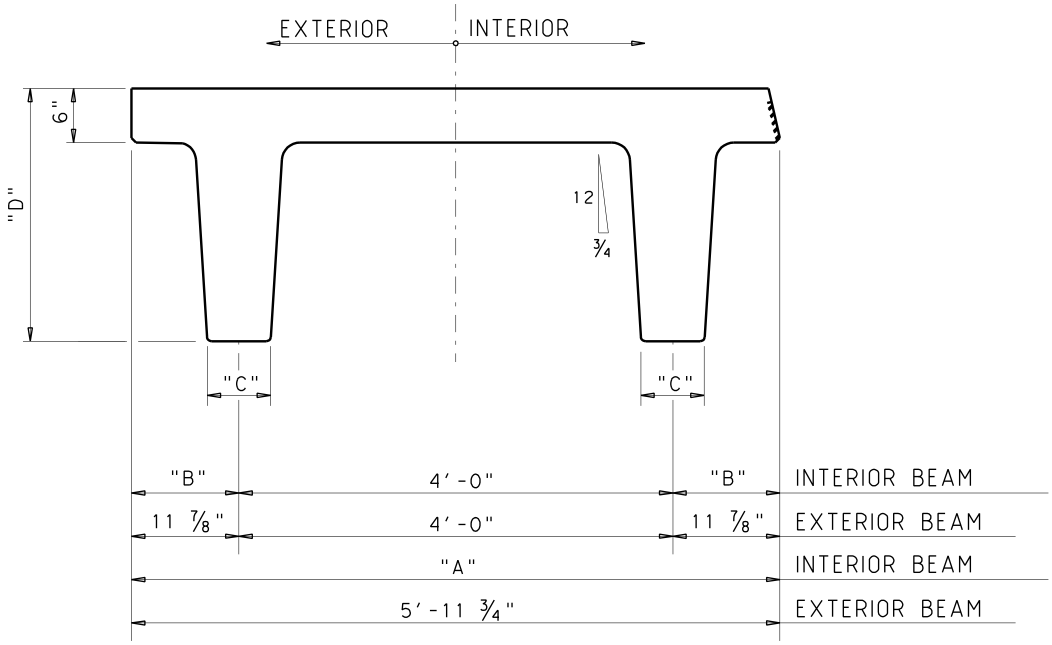


Figure 7 – Box Beam Shear Key Definition with CPR1 Cards

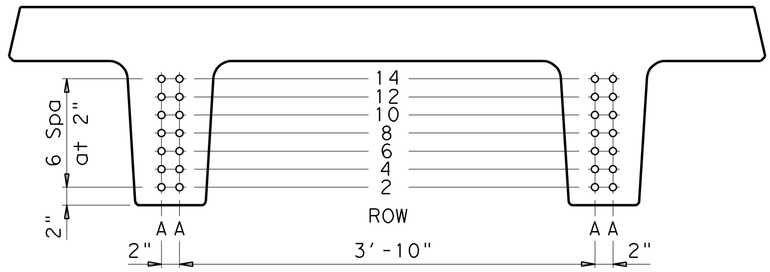


SECTIONS

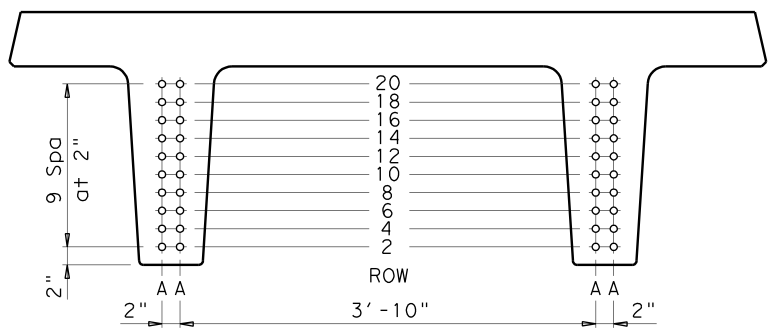
BEAM DIMENSIONS				
Beam Type	"A"	"B"	"C"	"D"
6T22	5′-11 ¾"	11 ⅞"	7 ¾"	1′-10"
7T22	6′-11 ¾"	1′-5 ⅞"		
8T22	7′-11 ¾"	1′-11 ⅞"		
6T28	5′-11 ¾"	11 ⅞"	7"	2′-4"
7T28	6′-11 ¾"	1′-5 ⅞"		
8T28	7′-11 ¾"	1′-11 ⅞"		
6T36	5′-11 ¾"	11 ⅞"	6"	3′-0"
7T36	6′-11 ¾"	1′-5 ⅞"		
8T36	7′-11 ¾"	1′-11 ⅞"		
6HT22	5′-11 ¾"	1′-1 ⅞"	11 ¾"	1′-10"
7HT22	6′-11 ¾"	1′-7 ⅞"		
8HT22	7′-11 ¾"	2′-1 ⅞"		
6HT28	5′-11 ¾"	1′-1 ⅞"	11"	2′-4"
7HT28	6′-11 ¾"	1′-7 ⅞"		
8HT28	7′-11 ¾"	2′-1 ⅞"		
6HT36	5′-11 ¾"	1′-1 ⅞"	10"	3′-0"
7HT36	6′-11 ¾"	1′-7 ⅞"		
8HT36	7′-11 ¾"	2′-1 ⅞"		

BEAM SECTION PROPERTIES					
Beam Type	Yb (in)	Yt (in)	Area (in^2)	I (in^4)	Weight (plf)
6T22	14.74	7.26	706	26395	735
7T22	15.13	6.87	778	27797	810
8T22	15.46	6.54	850	28998	885
6T28	18.77	9.23	795	51233	828
7T28	19.29	8.71	867	54010	903
8T28	19.73	8.27	939	56395	978
6T36	24.15	11.85	899	98984	936
7T36	24.81	11.19	971	104422	1011
8T36	25.37	10.63	1043	109138	1086
6HT22	13.70	8.30	834	34048	869
7HT22	14.13	7.87	906	36122	944
8HT22	14.48	7.52	978	37922	1019
6HT28	17.36	10.64	971	67033	1011
7HT28	17.89	10.11	1043	71159	1086
8HT28	18.35	9.65	1115	74780	1161
6HT36	22.22	13.78	1139	132841	1186
7HT36	22.86	13.14	1211	140925	1261
8HT36	23.43	12.57	1283	148125	1336

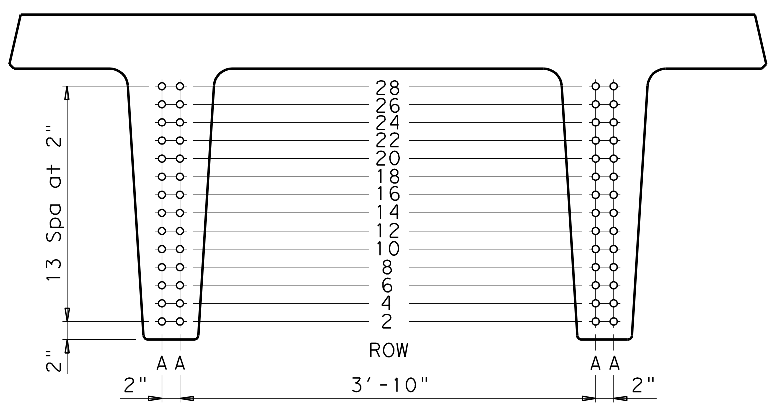
Figure 8 – Standard Double-T and HT Cross Section Properties



TxDOT T22 DBL-T BEAM

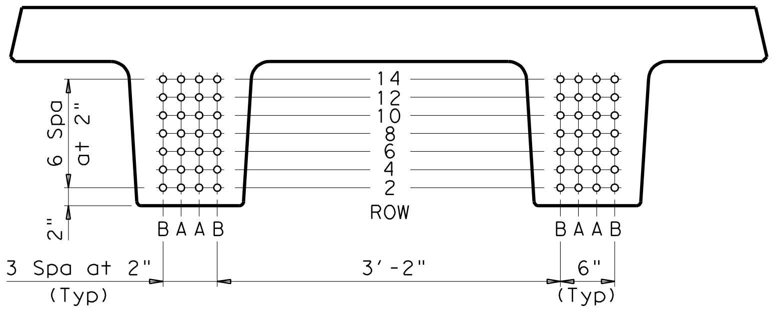


TxDOT T28 DBL-T BEAM

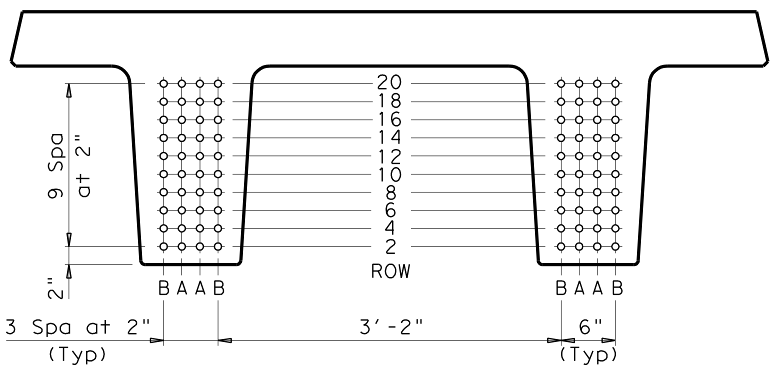


TxDOT T36 DBL-T BEAM

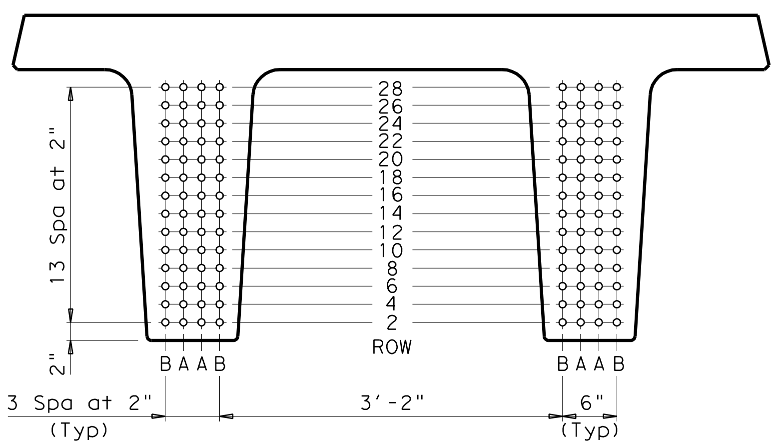
Figure 9 – Standard Double-T Beam Strand Grids



TxDOT HT22 DBL-T BEAM

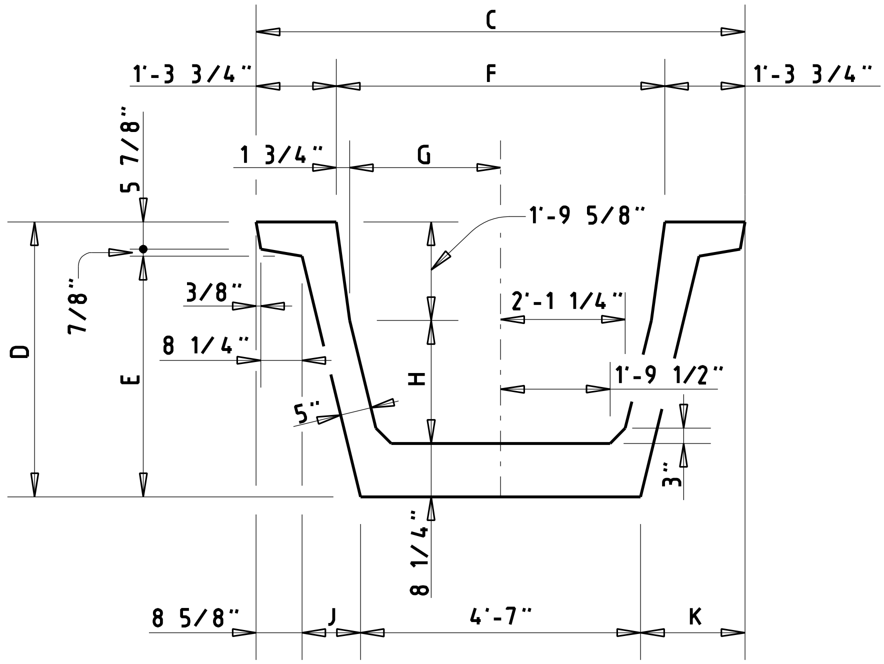


TxDOT HT28 DBL-T BEAM



TxDOT HT36 DBL-T BEAM

Figure 10 – Standard Double HT Beam Strand Grids



Beam Type	C (in)	D (in)	E (in)	F (in)	G (in)	H (in)	J (in)	K (in)	Yt (in)	Yb (in)	Area (in^2)	I (in^4)	Weight (plf)
U40	89	40	33.25	57.5	27	10.125	8.375	17.0	23.65	16.35	977.0	183,050	1,017
U54	96	54	47.25	64.5	30.5	24.125	11.875	20.5	31.54	22.46	1121.1	403,458	1,168

Figure 11 – Standard U Beam Cross Section Properties

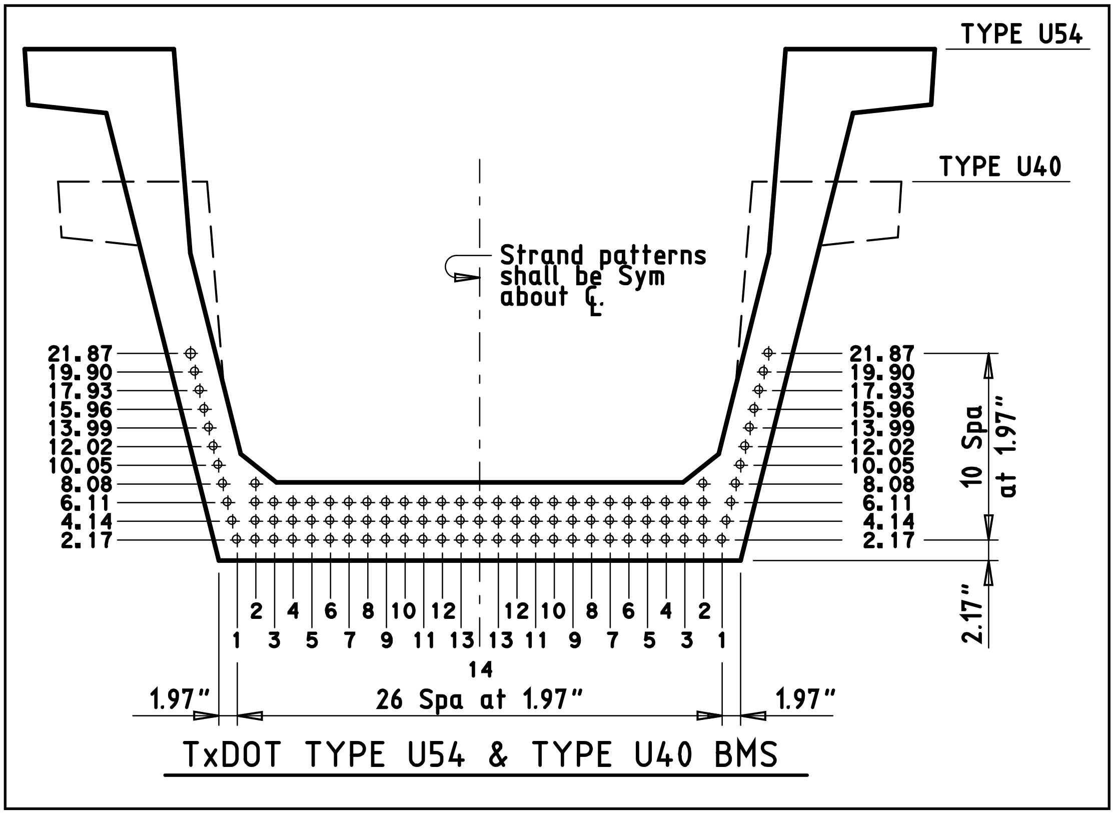
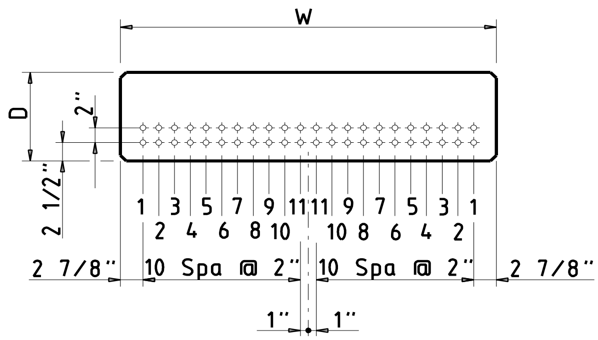
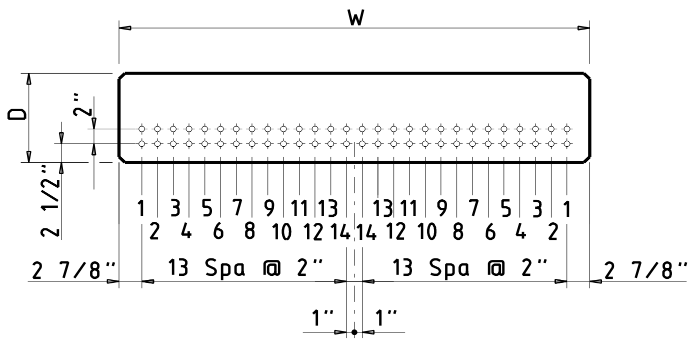


Figure 12 – Standard U Beam Strand Grid



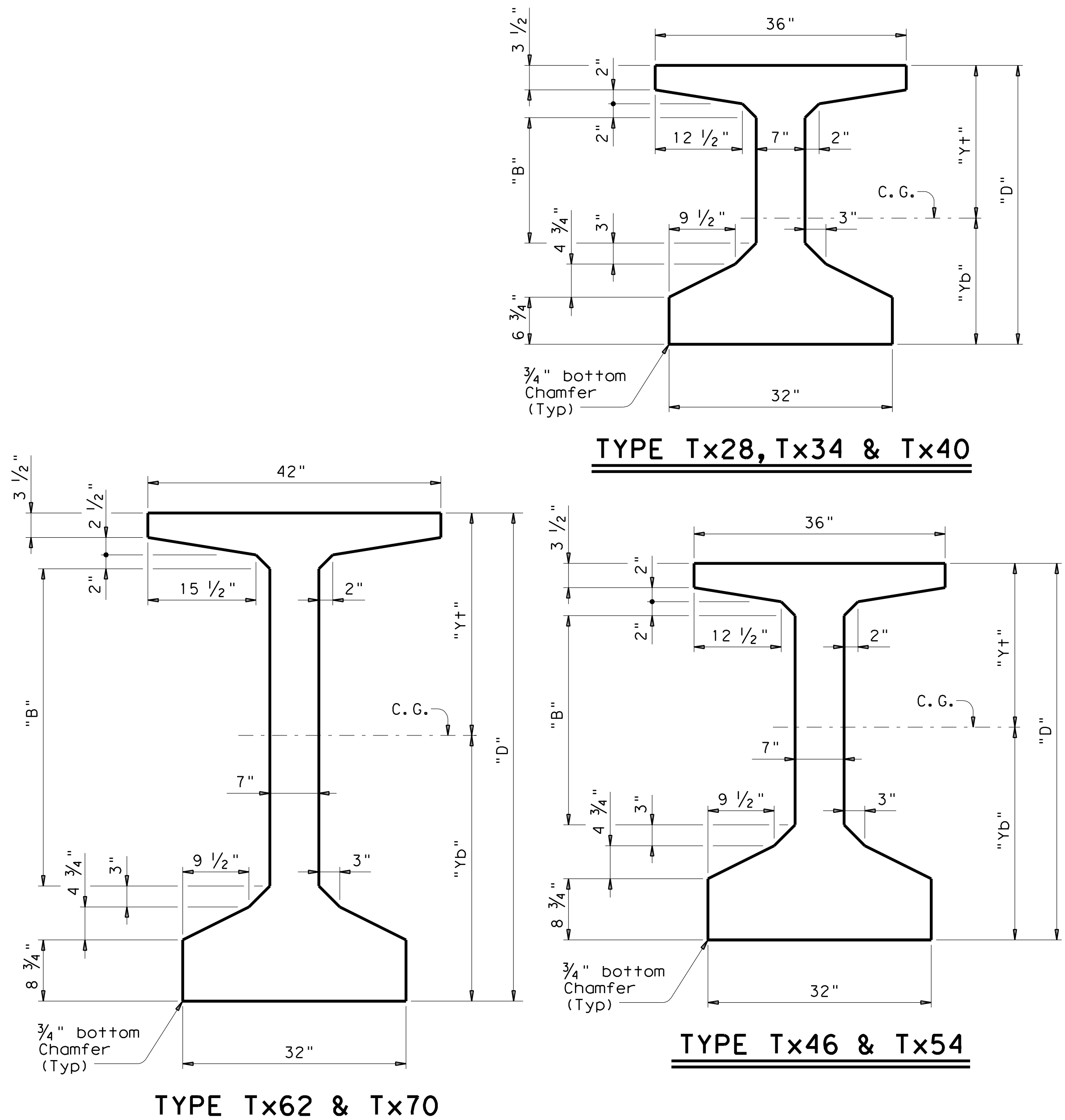
TxDOT 4SB SLAB BEAM



TxDOT 5SB SLAB BEAM

Beam Type	W (ft)	D (in)	Yb (in)	Yt (in)	Area (in^2)	I (in^4)	Weight (plf)
4SB12	3'-11 3/4"	12	6.0	6.0	573.0	6,876	597
4SB15	3'-11 3/4"	15	7.5	7.5	716.2	13,429	746
5SB12	4'-11 3/4"	12	6.0	6.0	717.0	8,604	747
5SB15	4'-11 3/4"	15	7.5	7.5	896.2	16,805	934

Figure 13 – Standard Slab Beam Cross Section Properties and Strand Pattern



GIRDER DIMENSIONS AND SECTION PROPERTIES								
Girder Type	"D" (in.)	"B" (in.)	"Yt" (in.)	"Yb" (in.)	Area ($in.^2$)	"Ix" ($in.^4$)	"Iy" ($in.^4$)	Weight (plf)
Tx28	28	6	15.02	12.98	585	52,772	40,559	610
Tx34	34	12	18.49	15.51	627	88,355	40,731	653
Tx40	40	18	21.90	18.10	669	134,990	40,902	697
Tx46	46	22	25.90	20.10	761	198,089	46,478	793
Tx54	54	30	30.49	23.51	817	299,740	46,707	851
Tx62	62	37 ½"	33.72	28.28	910	463,072	57,351	948
Tx70	70	45 ½"	38.09	31.91	966	628,747	57,579	1,006

Figure 14 – Standard TxGirder Cross Section Properties

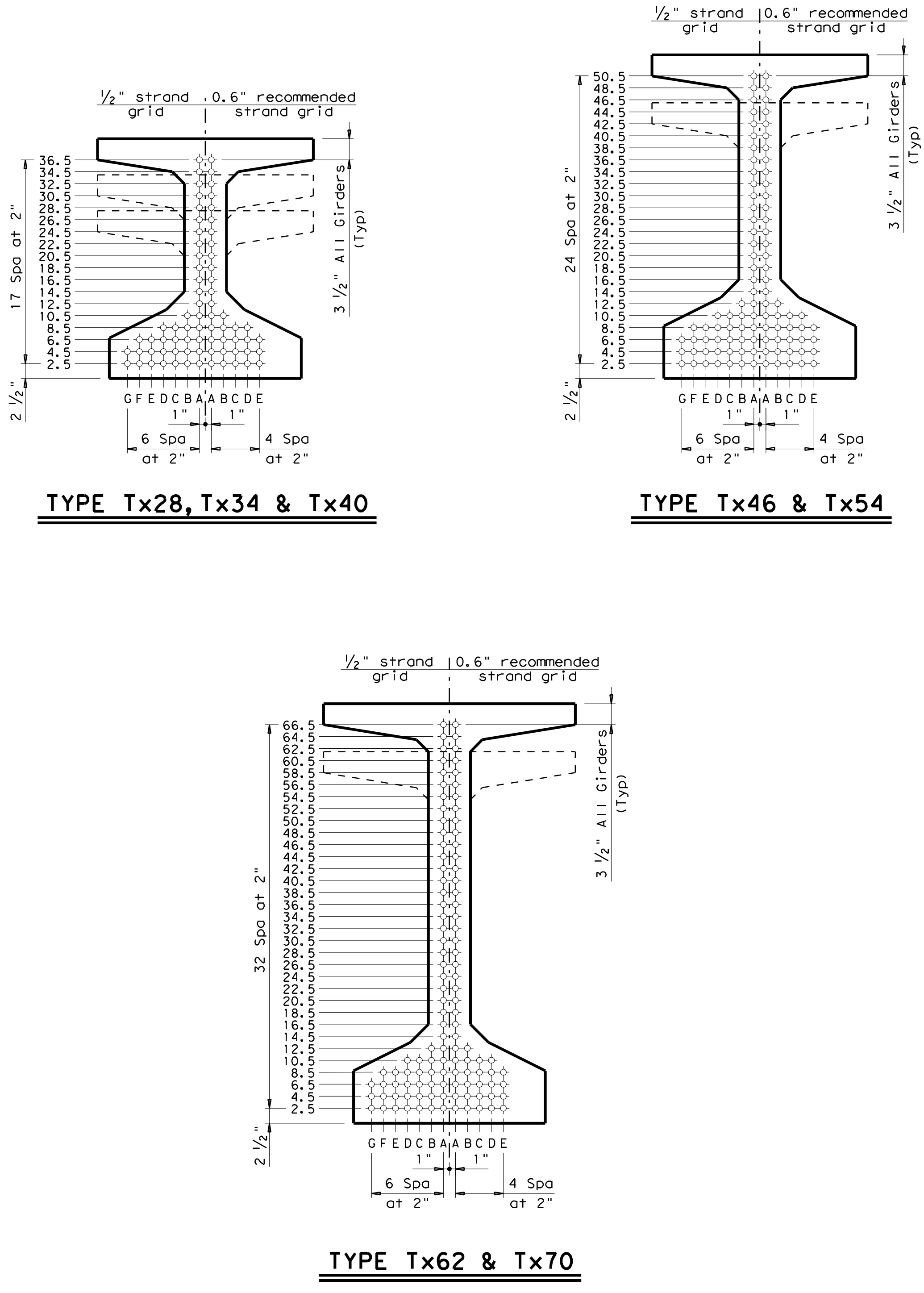
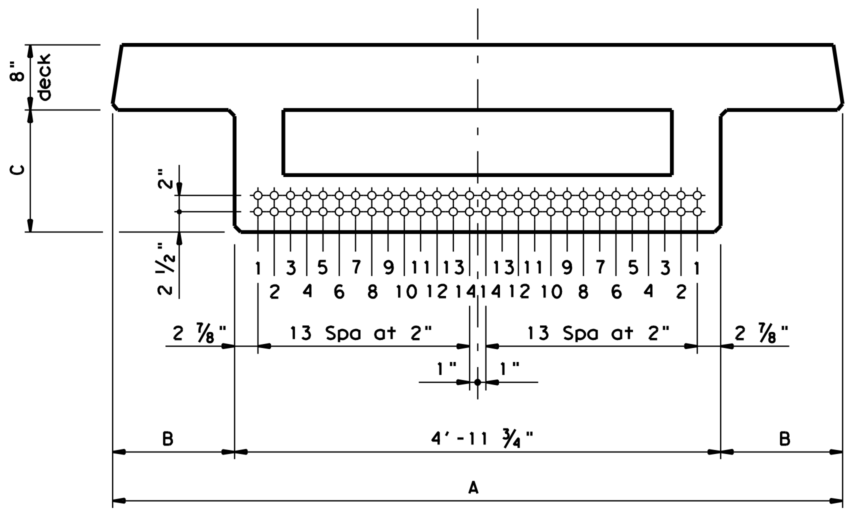


Figure 15 – Standard TxGirder Strand Grids

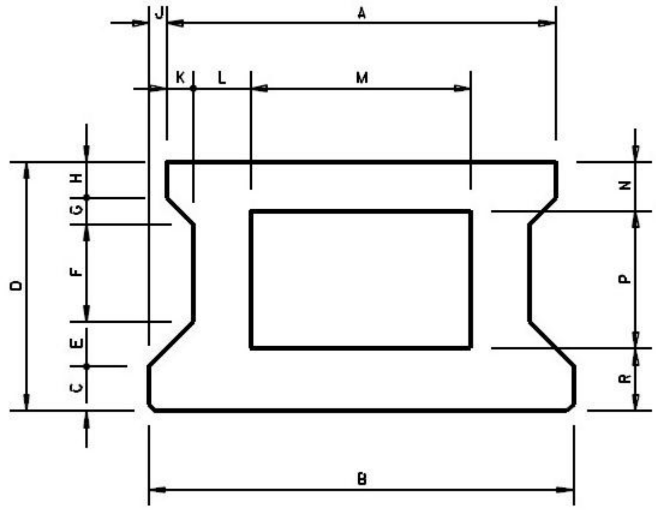
Note: The default is the ½ strand grid. Recommended strand grids must be implemented by defining the strand grid using the MSPR & LOCR – Prestressing Strand Grid cards.



TxDOT DECKED SLAB BEAM

BEAM DIMENSIONS AND SECTION PROPERTIES								
Beam Type	A (ft)	B (ft)	C (ft)	Yt (in)	Yb (in)	Area (in²)	I (in⁴)	Weight (plf)
6DS20	6'-5 ¾"	9"	1'-0"	9.18	10.82	1,087	43,704	1,132
7DS20	7'-5 ¾"	1'-3"	1'-0"	8.76	11.24	1,183	46,580	1,232
8DS20	7'-11 ¾"	1'-6"	1'-0"	8.57	11.43	1,231	47,879	1,282
6DS23	6'-5 ¾"	9"	1'-3"	10.46	12.54	1,123	64,997	1,170
7DS23	7'-5 ¾"	1'-3"	1'-3"	9.95	13.05	1,219	69,202	1,270
8DS23	7'-11 ¾"	1'-6"	1'-3"	9.73	13.27	1,267	71,095	1,320

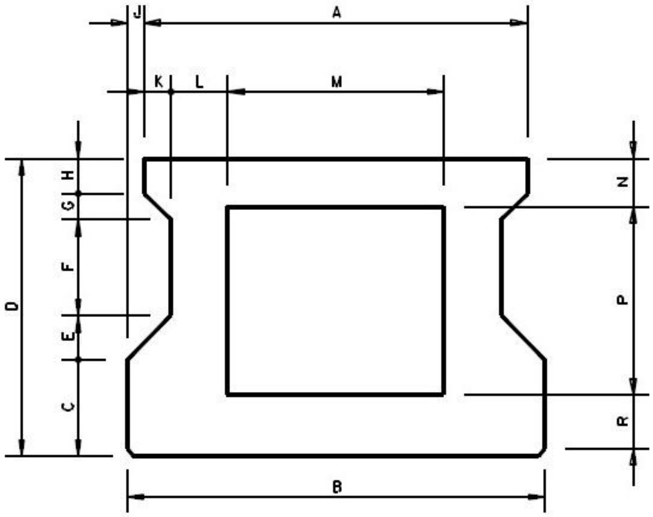
Figure 16 – Standard Decked Slab Girder Cross Section Properties and Strand Grid



BEAM TYPE				
Variable	4BX20	5BX20	4BX28	5BX28
A	3'-7 3/4"	4'-7 3/4"	3'-7 3/4"	4'-7 3/4"
B	3'-11 3/4"	4'-11 3/4"	3'-11 3/4"	4'-11 3/4"
C	5"	5"	5"	5"
D	1'-8"	1'-8"	2'-4"	2'-4"
E	4"	4"	5"	5"
F	4"	4"	11"	11"
G	2"	2"	3"	3"
H	5"	5"	4"	4"
J	2"	2"	2"	2"
K	2"	2"	3"	3"
L	7 1/2"	7 1/2"	6 1/2"	6 1/2"
M	2'0 3/4"	3'-0 3/4"	2'-0 3/4"	3'-0 3/4"
N	5 1/2"	5 1/2"	5 1/2"	5 1/2"
P	7 1/2"	7 1/2"	1'-3 1/2"	1'-3 1/2"
R	7"	7"	7"	7"
Y_{top} (in)	10.47	10.47	14.86	14.87
Y_{bott} (in)	9.53	9.53	13.14	13.13
Area (in^2)	689	839	781	931
I (in^4)	29,124	36,621	72,798	90,793
Wt/Lf(lbs)	718	874	813	970

Figure 17 – Standard X Beam Cross Section Properties A (20" and 28" Depths)[6]

[6] The "B" must be dropped from the X Beam Cross section designation when entering it on the BEAM Card in the "Beam Type" field, columns 16-20 (e.g., a 4BX20 must be entered as "4X20").



BEAM TYPE				
Variable	4BX34	5BX34	4BX40	5BX40
A	3′-7 3/4"	4′-7 3/4"	3′-7 3/4"	4′-7 3/4"
B	3′-11 3/4"	4′-11 3/4"	3′-11 3/4"	4′-11 3/4"
C	11"	11"	1′-5"	1′-5"
D	2′-10"	2′-10"	3′-4"	3′-4"
E	5"	5"	5"	5"
F	11"	11"	11"	11"
G	3"	3"	3"	3"
H	4"	4"	4"	4"
J	2"	2"	2"	2"
K	3"	3"	3"	3"
L	6 1/2"	6 1/2"	6 1/2"	6 1/2"
M	2′0 3/4"	3′-0 3/4"	2′-0 3/4"	3′-0 3/4"
N	5 1/2"	5 1/2"	5 1/2"	5 1/2"
P	1′-9 1/2"	1′-9 1/2"	2′-3 1/2"	2′-3 1/2"
R	7"	7"	7"	7"
Y_{top} (in)	18.41	18.39	21.82	21.80
Y_{bott} (in)	15.59	15.61	18.18	18.20
Area (in^2)	919	1,069	1,057	1,207
I (in^4)	123,757	152,730	190,840	233,453
Wt/Lf(lbs)	957	1,113	1,101	1,257

Figure 18 – Standard X Beam Cross Section Properties A (34” and 40” Depths)[7]

[7] See footnote for Figure 17 – Standard X Beam Cross Section Properties A (20” and 28” Depths).

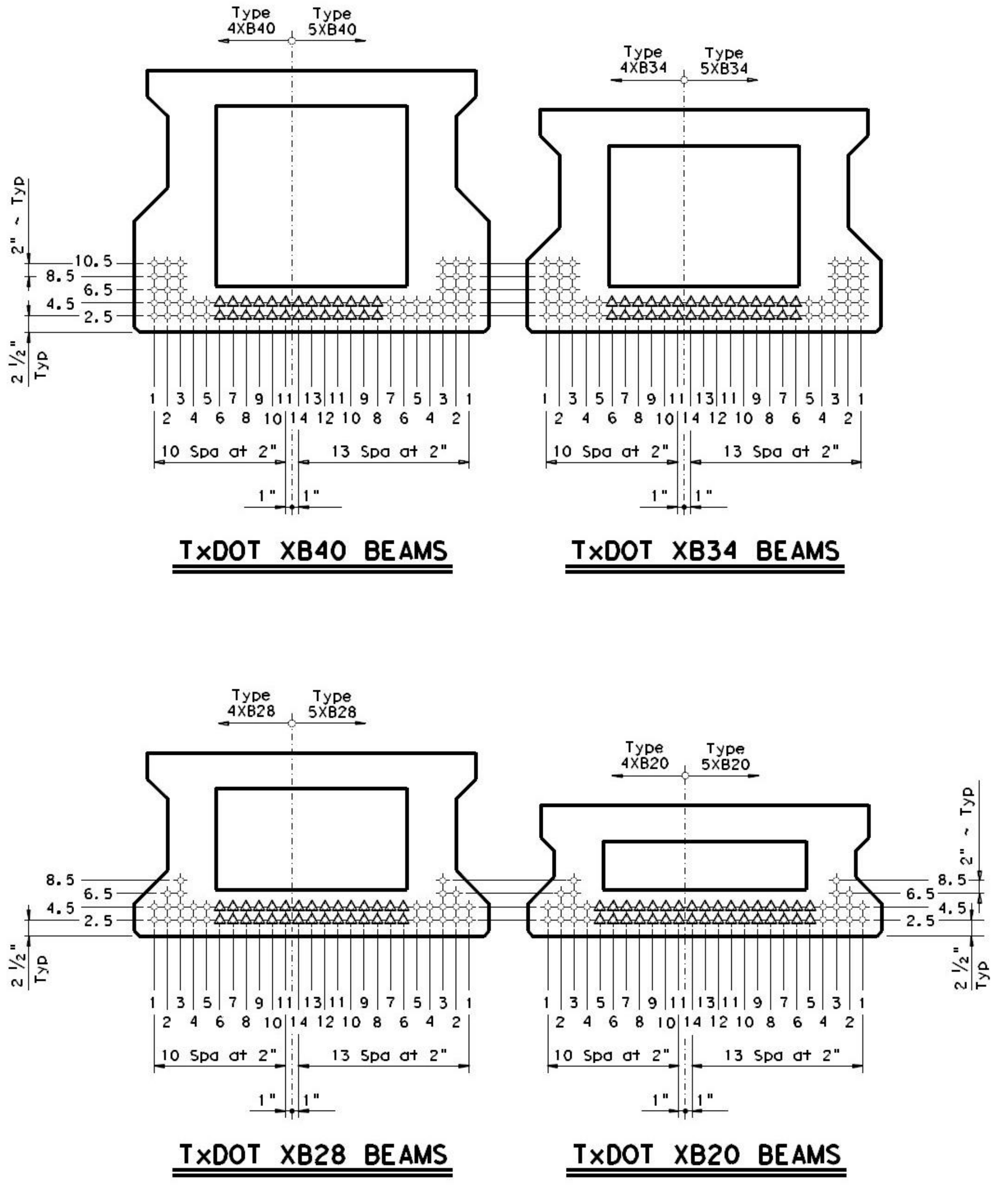


Figure 19 – Standard X Beam Strand Grids

Appendix B – Input Examples

The following example problems are contained in an Example folder of the *PSTRS14* program group. Only input files (no output) with brief explanations of each problem are shown below. Comments are annotated throughout the input files show the correct location of all input data fields. The first character on each comment line is a dollar sign ($) telling PSTRS14 to ignore that line for input. Experienced PSTRS14 users may want to remove these “annotations” to simplify the input. Coding the input can be a bit easier when every line contains input data.

Example 1: Design of Standard I Beam

The following is input for the most common type of PSTRS14 run. For LRFD, both the moment live load distribution factor input on the BEAM card and shear live load distribution factor input on the LLDF card are required input.

Design Data:

AASHTO LRFD 2007 Specifications with 2004 Losses
Type IV Beam
C/C Bearing Span Length = 108.58’ (110 ft Span)
Beam Spacing = 8.5’
Slab Thickness = 8”
Relative Humidity = 60%
Uniform Dead Load on Composite Section (excluding overlay) = 0.132 kip/ft
(2 T501 Rails, distributed to 5 beams)
Moment Live Load Distribution Factor = 0.696 (AASHTO LRFD 4.6.2.2.2b-1(k))
Shear Live Load Distribution Factor = 0.849 (AASHTO LRFD 4.6.2.2.3a-1(k))

Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777777778
$234567890123456789012345678901234567890123456789012345678901234567890123456789O
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 1: LRFD Spec, 110 ft Span, Type IV, 8.5' Bm Spacing, 8.0" Slab
PROB Standard I-Beam using 2004 LRFD Specs
$MAT1        MoE                           MoE
$MAT1        of                            of
$MAT1        Beam                          Slab
MAT1         5000.0                        5000.0
$OUTP   LF - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF - SF is default and it omits the listed LF tables
OUTP    LF
$SPEC    X,  where: 0=95/02 Stnd Spec(default), 1=94 Stnd Spec,
$SPEC    |          5=2004-2007 LRFD, 9=2009-2010 LRFD, A=2012 LRFD
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    |(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     54
$LLDF     Shear
$LLDF     LLDF
LLDF      0.849
$BEAMSpan Beam Beam           Beam Slab Comp Mom                    UDL on
$    LabelLabelType SpanLengthSpac.ThickSlab LLDF    RH             Comp Sec
BEAM ALL  1    IV   108.58    8.500 8.0      0.696   60             0.132
```

Example 2: Design of Standard I Beam with Standard Specifications

Same as **Example 1: Design of Standard I Beam**, except using the 1995/2002 AASHTO Standard Specifications.

Design Data:

AASHTO Standard Specifications 1995/2002
Type IV Beam
C/C Bearing Span Length = 108.58’ (110 ft Span)
Beam Spacing = 8.5’
Slab Thickness = 8”
Relative Humidity = 60%
Uniform Dead Load on Composite Section (excluding overlay) = 0.132 kip/ft
(2~T501 Rails, distributed to 5 beams)
Moment Live Load Distribution Factor is calculated internally by PSTRS14
Shear Live Load Distribution Factor is not required for Standard Specifications

Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777778
$23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 2: 95/02 Standard Spec, 110 ft Span, Type IV, 8.5' Bm Spacing, 8.0" Slab
PROB Same as Example 1, but design with Standard Specifications
$MAT1        MoE                          MoE
$MAT1        of                           of
$MAT1        Beam                         Slab
MAT1         5000.0                       5000.0
$OUTP   LF - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF - SF is default and it omits the listed LF tables
OUTP    LF
$SPEC    X,  where: 0=95/02 Stnd Spec(default), 1=94 Stnd Spec
SPEC     0
$BEAMSpan Beam Beam           Beam Slab Comp Mom                      UDL on
$    LabelLabelType SpanLengthSpac.ThickSlab LLDF    RH               Comp Sec
BEAM ALL  1    IV   108.58    8.500 8.0              60               0.132
```

Example 3: Analysis of Standard I Beam

The following input is for an analysis of the beam designed in **Example 1: Design of Standard I Beam**. The design data required is as follows.

Design Data:

AASHTO LRFD 2007 Specifications with 2004 Losses
Initial Concrete Strength = 5367 psi (Orig. Design)
Final Concrete Strength = 5367 psi (Orig. Design)
Number of Strands = 56 (Orig. Design)
End Eccentricity = 10.32 inches (Orig. Design)
Mid-span Eccentricity = 18.89 inches (Orig. Design)
Top Fiber Stress at Mid-span due to Total External Loads = 3823 psi (Orig. Design)
Bottom Fiber Stress at Mid-span due to Total External Loads = -4195 psi (Orig. Design)
Ultimate Moment Required due to Factored External Loads = 7189 kip-ft (Orig. Design)

Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 3: LRFD Spec, 110 ft Span, Type IV, 8.5' Bm Spacing, 8.0" Slab
PROB Analysis of Beam from Example 1 (designed per LRFD Specifications)
$MAT1         MoE                           MoE
$MAT1         of                            of
$MAT1         Beam                          Slab
MAT1          5000.0                        5000.0
$OUTP   LF - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF - SF is default and it omits the listed LF tables
OUTP    LF
$SPEC     X,  where: 0=95/02 Stnd Spec(default), 1=94 Stnd Spec,
$SPEC     |          5=2004-2007 LRFD, 9=2009-2010 LRFD, A=2012 LRFD
$SPEC     |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC     ||         A=TxDOT 2012 losses
$SPEC     |(Design Spec default= 0 for SS & AREMA)
$SPEC     ||(Losses Spec default= 4 for LRFD)
SPEC      54
$LLDF      Shear
$LLDF      LLDF
LLDF       0.849
$CGSL  Num End      CL
$CGSL  Str Eccentr. Eccentr.
CGSL    56 10.32    18.89
$ANLY      Top Fiber Bot Fiber Ult. Mom  Release   Final
$ANLY      CL Stress CL Stress Required  Strength  Strength
ANLY       3823.     -4195.    7189.     5367.     5367.
$BEAMSpan Beam Beam           Beam Slab Comp Mom                      UDL on
$    LabelLabelType SpanLengthSpac.ThickSlab LLDF    RH               Comp Sec
BEAM ALL  1    IV   108.58    8.500 8.0      0.696   60               0.132
```

Example 4: Analysis of Standard I Beam with Standard Specifications

The following input is for an analysis of the beam designed in **Example 2: Design of Standard I Beam with Standard Specifications**. The design data required is as follows.

Design Data:

AASHTO Standard Specifications 1995/2002
Initial Concrete Strength Required = 5020 psi (Orig. Design)
Final Concrete Strength Required = 5887 psi (Orig. Design)
Number of Strands = 50 (Orig. Design)
End Eccentricity = 11.07 inches (Orig. Design)
Mid-span Eccentricity = 19.47 inches (Orig. Design)
Top Fiber Stress at Mid-span due to Total External Loads = 3690 psi (Orig. Design)
Bottom Fiber Stress at Mid-span due to Total External Loads = -4058 psi (Orig. Design)
Ultimate Moment Required due to Factored External Loads = 6866 kip-ft (Orig. Design)

Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 4: 95/02 Spec, 110 ft Span, Type IV, 8.5' Bm Spacing, 8.0" Slab
PROB Analysis of Beam from Example 2
$MAT1        MoE                            MoE
$MAT1        of                             of
$MAT1        Beam                           Slab
MAT1         5000.0                         5000.0
$OUTP   LF/ - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF  - SF is default and it omits these tables
OUTP    LF
$SPEC    X, where 0 = 95/02 specs (default), 1 = 94 Specs,  5 = LRFD Specs
SPEC     0
$CGSL  Num End      CL
$CGSL  Str Eccentr. Eccentr.
CGSL    50 11.07    19.47
$ANLY     Top Fiber Bot Fiber Ult. Mom  Release   Final
$ANLY     CL Stress CL Stress Required  Strength  Strength
ANLY      3690.     -4058.    6866.     5020.     5887.
$BEAMSpan Beam Beam           Beam Slab Comp Mom                      UDL on
$    LabelLabelType SpanLengthSpac.ThickSlab LLDF    RH               Comp Sec
BEAM ALL  1    IV   108.58    8.500 8.0              60               0.132
```

Example 5: Design of I Beam as Non-Standard with Non-Standard Live Load

This example shows how to define non-standard beams as well as non-standard live loads. The beam and loading are the same as the beam designed in **Example 1: Design of Standard I Beam**.

Input:

```
$        111111111122222222223333333333444444444455555555556666666666777777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 5: LRFD Spec, 110 ft Span, Type IV, 8.5' Bm Spacing, 8.0" Slab
PROB Same as Example 1 but with Beam and Live Load Defined as Non-standard
$MAT1        MoE                          MoE
$MAT1        of                           of
$MAT1        Beam                         Slab
MAT1         5000.0                       5000.0
$OUTP   LF - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF - SF is default and it omits the listed LF tables
OUTP    LF
$-------------Type IV Beam Defined as a non-standard Beam----------------------|
$         |----------Service---------------------|---Ultimate (Comp Zones)-----|
$NSCS     Area of Bm          Yb of Bm  I of Bm    Width    Max Depth    Yb
NSCS      788.4375            24.7513   260403.15  20.0     8.0          50.0
NSCS                                               14.0     6.0          43.0
NSCS                                               8.0      23.0         28.5
$MSPR Str/RowNo   No   No   No   No   No   No   No   No   No   No   No   No   No
$LOCR Yb  ####.####.####.####.####.####.####.####.####.####.####.####.####.####.
MSPR        12   12   12   10    8    6    4    2    2    2    2    2    2    2
LOCR        2.   4.   6.   8.  10.  12.  14.  16.  18.  20.  22.  24.  26.  28.
MSPR         2    2    2    2    2    2    2    2    2    2    2    2
LOCR       30.  32.  34.  36.  38.  40.  42.  44.  46.  48.  50.  52.
$SHRS     Web width    Legs Bar
SHRS      8.0          2    4
$--------------------HL-93 Load Defined as a Non-standard Load ----------------|
$LVEC   SP - SP=Superimposed with uniform ld, blank=larger of uniform or truck
$LVEC       Load      Load      Load
$LOCL     Distance  Distance  Distance from first concentrated live load
LVEC    SP   42.56    42.56    10.64
LOCL          0.      14.      28.
$LVEU     Load
$LOCL    Length
LVEU      0.64
LOCL      108.580
$SPEC    X,  where: 0=95/02 Stnd Spec(default), 1=94 Stnd Spec,
$SPEC    |          5=2004-2007 LRFD, 9=2009-2010 LRFD, A=2012 LRFD
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    |(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     54
$LLDF     Shear
$LLDF     LLDF
LLDF      0.849
$BEAMSpan Beam Beam           Beam Slab Comp Mom       |V/S           UDL on
$    LabelLabelType SpanLengthSpac.ThickSlab LLDF    RH|Rat           Comp Sec
BEAM ALL  1    NS   108.58    8.500 8.0 8.5  0.696   604.76           0.132
```

Example 6: Design of Standard Double-T Beam

This example shows the input for design of a Standard Double-T beam. The design data required is as follows.

Design Data:

AASHTO LRFD 2007 Specifications with 2004 Losses
Type 8T36 Beam
C/C Bearing Span Length = 58.58’ (60 ft Span)
Beam Spacing = 8.02’
Slab Thickness = 5”
Relative Humidity = 60%
Uniform Dead Load on Composite Section (excluding overlay) = 0.162 kip/ft
Moment Live Load Distribution Factor = 0.772 (AASHTO LRFD 4.6.2.2.2b-1(i))
Shear Live Load Distribution Factor = 0.772 (AASHTO LRFD 4.6.2.2.2b-1(i))

Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 6: LRFD Spec, 60' Span, Type 8T36, 8.02' Bm Spacing, 5.0" Slab
PROB Old Standard Double-T beam using LRFD Specs
$MAT1        MoE                           MoE
$MAT1        of                            of
$MAT1        Beam                          Slab
MAT1         5000.0                        5000.0
$OUTP   LF - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF - SF is default and it omits the listed LF tables
OUTP    LF
$SPEC    X,  where: 0=95/02 Stnd Spec(default), 1=94 Stnd Spec,
$SPEC    |          5=2004-2007 LRFD, 9=2009-2010 LRFD, A=2012 LRFD
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    |(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     54
$LLDF     Shear
$LLDF     LLDF
LLDF      0.772
$BEAMSpan Beam Beam           Beam Slab Comp Mom                     UDL on
$    LabelLabelType SpanLengthSpac.ThickSlab LLDF    RH              Comp Sec
BEAM 60.0 8T36 8T36 58.58     8.02  5.0 8.0  0.772   60              0.162
```

Example 7: Design of Standard U Beam

This example shows the input for the design of a Standard U beam. The design data required is as follows.

Design Data:

AASHTO LRFD 2007 Specifications with 2004 Losses
Type U54 Beam
C/C Bearing Span Length = 118.42’ (120 ft Span)
Beam Spacing = 10.83’
Slab Thickness = 8.0”
Relative Humidity = 60%
Uniform Dead Load on Composite Section (excluding overlay) = 0.212 kip/ft
Moment Live Load Distribution Factor = 0.682 (AASHTO LRFD 4.6.2.2.2b-1(c))
Shear Live Load Distribution Factor = 0.978 (AASHTO LRFD 4.6.2.2.3a-1(c))

Input:

```
$        111111111122222222223333333333444444444455555555556666666666777777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 7: LRFD Spec, 120' ft Span, Type U54, 10.83' Bm Spacing, 8.0" Slab
PROB Standard U beam using LRFD Specs
$MAT1        MoE                           MoE
$MAT1        of                            of
$MAT1        Beam                          Slab
MAT1         5000.0                        5000.0
$OUTP   LF - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF - SF is default and it omits the listed LF tables
OUTP    LF
$SPEC    X,  where: 0=95/02 Stnd Spec(default), 1=94 Stnd Spec,
$SPEC    |          5=2004-2007 LRFD, 9=2009-2010 LRFD, A=2012 LRFD
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    |(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     54
$LLDF     Shear
$LLDF     LLDF
LLDF      0.978
$BEAMSpan Beam Beam           Beam Slab Comp Mom                      UDL on
$    LabelLabelType SpanLengthSpac.ThickSlab LLDF    RH               Comp Sec
BEAM ALL  INT  U54  118.42    10.83 8.0 10.830.682   60               0.212
```

Example 8: Design of Standard Slab Beam

The example shows the input for the design of a Standard Slab beam. The design data required is as follows.

Design Data:

AASHTO LRFD 2007 Specifications with 2004 Losses
Type 5SB15 Beam
C/C Bearing Span Length = 43.583' (45 ft Span)
Beam Spacing = 5.2'
Slab Thickness = 5.0"
Relative Humidity = 60%
Uniform Dead Load on Composite Section (excluding overlay) = 0.132 kip/ft
Moment Live Load Distribution Factor = 0.441 (AASHTO LRFD 4.6.2.2.2b-1(g))
Shear Live Load Distribution Factor = 0.441 (AASHTO LRFD 4.6.2.2.2b-1(g))

Input:

```
$        111111111122222222223333333333444444444455555555556666666666777777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 8: LRFD Spec, 45 ft Span, Type 5SB15, 5.2' Bm Spacing, 5" Slab
PROB Standard Slab Beam design using LRFD Specs
$OUTP   LF - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF - SF is default and it omits the listed LF tables
OUTP    LF
$MAT1        MoE                           MoE
$MAT1        of                            of
$MAT1        Beam                          Slab
MAT1         5000.0                        5000.0
$SPEC    X,  where: 0=95/02 Stnd Spec(default), 1=94 Stnd Spec,
$SPEC    |          5=2004-2007 LRFD, 9=2009-2010 LRFD, A=2012 LRFD
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    |(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     54
$LLDF     Shear
$LLDF     LLDF
LLDF      0.441
$BEAMSpan Beam Beam           Beam Slab Comp Mom                      UDL on
$    LabelLabelType SpanLengthSpac.ThickSlab LLDF    RH               Comp Sec
BEAM ALL  ALL  5SB15 43.583   5.2  5.0  5.2  0.441   60               0.132
```

Example 9: Analysis of Standard Slab Beam

This example input is for performing an analysis of the beam designed in **Example 8: Design of Standard Slab Beam**. The design data required is as follows.

Design Data:

AASHTO LRFD 2007 Specifications with 2004 Losses
Initial Concrete Strength Required = 4000 psi (Orig. Design)
Final Concrete Strength Required = 5000 psi (Orig. Design)
Number of Strands = 38 (Orig. Design)
Debonded Strands = 8 debonded to 3 ft, 4 debonded to 6 ft (Orig. Design)
Top Fiber Stress at Mid-span due to Total External Loads = 2181 psi (Orig. Design)
Bottom Fiber Stress at Mid-span due to Total External Loads = -2572 psi (Orig. Design)
Ultimate Moment Required due to Factored External Loads = 1057 kip-ft (Orig. Design)

Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 9: LRFD Spec, 45 ft Span, Type 5SB15, 5.2' Bm Spacing, 5" Slab
PROB Analysis of Beam from Example 8
$MAT1        MoE                           MoE
$MAT1        of                            of
$MAT1        Beam                          Slab
MAT1         5000.0                        5000.0
$OUTP   LF - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF - SF is default and it omits the listed LF tables
OUTP    LF
$SPEC    X,  where: 0=95/02 Stnd Spec(default), 1=94 Stnd Spec,
$SPEC    |          5=2004-2007 LRFD, 9=2009-2010 LRFD, A=2012 LRFD
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    |(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     54
$LLDF     Shear
$LLDF     LLDF
LLDF      0.441
$STPR Strand No
$LOCR Yb   #.##
STPR    CL   26
LOCR       2.50
$DBPR Length No
$LOCR Yb   #.##
DBPR 3.0      8
LOCR       2.50
DBPR 6.0      4
LOCR       2.50
$ANLY     Top Fiber Bot Fiber Ult. Mom  Release   Final
$ANLY     CL Stress CL Stress Required  Strength  Strength
ANLY      2181.     -2572.    1057.     4000.     5000.
$BEAMSpan Beam Beam           Beam Slab Comp Mom                      UDL on
$    LabelLabelType SpanLengthSpac.ThickSlab LLDF    RH               Comp Sec
BEAM ALL  ALL  5SB15 43.583   5.2  5.0  5.2  0.441   60               0.132
```

Example 10: Design of Standard Box Beam

This example illustrates the input required to design a standard Box beam. To satisfy the design criteria of not accounting for composite action between beams and shear keys, the modulus of elasticity and concrete strength of the shear key are input as very small values. The design data required is as follows.

Design Data:

AASHTO LRFD 2007 Specifications with 2004 Losses
Type 5B20 Beam, No slab
C/C Bearing Span Length = 28.4167' (30 ft Span)
Beam Spacing = 5.063'
Relative Humidity = 60%
Uniform Dead Load on Composite Section (excluding overlay) = 0.163 kip/ft
Uniform Dead Load on Composite Section (due to overlay) = 0.130 kip/ft
Moment Live Load Distribution Factor = 0.428 (AASHTO LRFD 4.6.2.2.2b-1(g))
Shear Live Load Distribution Factor = 0.650 (AASHTO LRFD 4.6.2.2.3a-1(g))

Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 10: LRFD Spec, 30 ft Span, Type 5B20, 5.063' Bm Spacing
PROB Standard Box Beam design using LRFD Specs
$MAT1        MoE                         MoE              MOE
$MAT1        of                          of               of
$MAT1        Beam                        Slab             Key
MAT1         5000.0                      5000.0           0.001
$OUTP   LF - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF - SF is default and it omits the listed LF tables
OUTP    LF
$SPEC    X,  where: 0=95/02 Stnd Spec(default), 1=94 Stnd Spec,
$SPEC    |          5=2004-2007 LRFD, 9=2009-2010 LRFD, A=2012 LRFD
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    |(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     54
$LLDF     Shear
$LLDF     LLDF
LLDF      0.650
$BEAMSpan Beam Beam           Beam Slab Comp Mom            UDL       UDL on
$    LabelLabelType SpanLengthSpac.ThickSlab LLDF    RH     Overlay   Comp Sec
BEAM ALL  ALL  5B20 28.4167   5.063          0.428   60     0.130     0.163
```

Example 11: Design of Standard Exterior Box Beam

This example illustrates the input required to design a standard exterior Box Beam using design data from **Example 10: Design of Standard Box Beam**. The program can automatically account for the shear keys between box beams. However, the program's treatment of shear keys does not work for exterior beams that only have a shear key on one side. There are several ways to deal with this, such as neglecting the key's effect on the composite section properties by turning off the shear key option with the OPTL card and then adding the weight of one shear key as a uniform load on the non-composite section. Another method transforms the shear keys into a single shear key by using a modulus of elasticity equal to half that of the slab (i.e. $E_{Shear\ Key} = E_{Slab} / 2$) and then subtracting off the weight of one shear key.

In this example, the modulus of elasticity and concrete strength of the shear key are input as very small values to prevent composite action, just as in **Example 10: Design of Standard Box Beam**. By doing this, the dead load and deflection of the shear keys are still calculated. The weight of one shear key is then subtracted by using a negative uniform load on the non-composite section, input on the SPEC card.

Also, exterior Box beams must have interior diaphragms spaced at no more than 10 ft. The weight of these diaphragms are added using the LOAD and LOCL cards.

Design Data:

Moment Live Load Distribution Factor = 0.446 (AASHTO 4.6.2.2.2d-1 (g))
Shear Live Load Distribution Factor = 0.684 (AASHTO 4.6.2.2.3b-1 (g))

Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 11: LRFD Spec, 30 ft Span, Type 5B20, 5.063' Bm Spacing, ACP Overlay
PROB Exterior 5B20 with Diaphragms and half Shear key
$MAT1        MoE                         MoE              MOE
$MAT1        Beam                        Slab             Key
MAT1         5000.0                      5000.0           0.001     0.001
$OUTP   LF - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF - SF is default and it omits the listed LF tables
OUTP    LF
$SPEC    X,where: 0=95/02 Stnd Spec(default), 1=94 Stnd Spec, 5=2004-2007 LRFD..
$SPEC    |Y,where: 0=1994 losses,4=2004 losses,7=2007 losses,A=TxDOT2012 losses
$SPEC    |(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
$    Use this to subtract half of the shear key dead load (Exterior Beam)
$SPEC    ||    XXXXX = Uniform dead load on non-composite section
SPEC     54    -0.05
$Interior Diaphragm Loads (For exterior beams only)
$       NCDead Load Dead Load
LOAD    NC 0.314     0.314
$         Load Loc  Load Loc
LOCL       9.208     19.208
$LLDF     Shear
$LLDF     LLDF
LLDF      0.684
$BEAMSpan Beam Beam           Beam Slab Comp Mom            UDL       UDL on
$    LabelLabelType SpanLengthSpac.ThickSlab LLDF    RH     Overlay   Comp Sec
BEAM ALL  ALL  5B20 28.4167   5.063          0.446   60     0.130     0.163
```

Example 12: Standard I Beam Optional Design Check

This example shows an optional design check using an input form from **Appendix C – Optional Design Input Forms**. This optional design check is for the original beam designed in **Example 1: Design of Standard I Beam**, with a different size strand. The design data required is as follows.

Design Data:

Strand Size = 0.600 (New); ½ (Orig. Design)
Number of Strands = 38 (New); 56 (Orig. Design)
End Eccentricity = 10.32 inches (Orig. Design)
Mid-span Eccentricity = 18.89 inches (Orig. Design)
Initial Concrete Strength Required = 5367 psi (Orig. Design)
Final Concrete Strength Required = 5367 psi (Orig. Design)
Top Fiber Stress at Mid-span due to Total External Loads = 3823 psi (Orig. Design)
Bottom Fiber Stress at Mid-span due to Total External Loads = -4195 psi (Orig. Design)
Ultimate Moment Required due to Factored External Loads = 7189 kip-ft (Orig. Design)

Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 12: LRFD Spec, 110 ft Span, Type IV, 8.5' Bm Spacing, 8.0" Slab
PROB Optional Design Check for Example 1 using Optional Design Forms
$BEAMSpan Beam Beam           Beam Slab Comp Mom
$    LabelLabelType SpanLengthSpac.ThickSlab LLDF    RH
BEAMF          IV   108.58    8.500 8.0      0.696   60
$ANLY     Top Fiber Bot Fiber Ult. Mom  Release   Final
$ANLY     CL Stress CL Stress Required  Strength  Strength
ANLY      3823.     -4195.    7189.     5367.     5367.
$STRD Size
STRD  .600
$MAT1        MoE                           MoE
$MAT1        of                            of
$MAT1        Beam                          Slab
MAT1         5000.0                        5000.0
$SPEC    X,  where: 0=95/02 Stnd Spec(default), 1=94 Stnd Spec,
$SPEC    |          5=2004-2007 LRFD, 9=2009-2010 LRFD, A=2012 LRFD
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    |(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     54
$STPR Strand No
$LOCR Yb   #.##
STPR    CL   12   12   12    2
LOCR       2.00 4.00 6.00 8.00
$STPR Strand No
$LOCR Yb   #.##
STPR    ED   10   10   10    0    2    2    2    2
LOCR       2.00 4.00 6.00 8.0046.0048.0050.0052.00
$LLDF     Shear
$LLDF     LLDF
LLDF      0.849
$ACAM - Camber comparison, input original design info
$    Orig  Orig      Orig           Orig
$      No. Ecc       Ecc            strd
$     Strd @End      @CL            size
ACAM    56 10.32     18.89          1/2
```

Example 13: Standard Slab Beam Optional Design Check

This example shows an optional design check using an input form from **Appendix C – Optional Design Input Forms**. This optional design check is for the original beam designed in **Example 8: Design of Standard Slab Beam**, with a different strand area. The design data required is as follows.

Design Data:

Strand Area = 0.167 (New); 0.153 (Original Des)
Number of Strands = 24 (New); 26 (Original Des)
Debonded Strands = 8 debonded to 3 ft, 4 debonded to 6 ft (New)
Initial Concrete Strength Required = 4000 psi (Original Des)
Final Concrete Strength Required = 5000 psi (Original Des)
Top Fiber Stress at Mid-span due to Total External Loads = 2181 psi (Original Des)
Bottom Fiber Stress at Mid-span due to Total External Loads = -2572 psi (Original Des)
Ultimate Moment Required due to Factored External Loads = 1057 kip-ft (Original Des)

Input:

```
$        11111111112222222222333333333344444444445555555555666666666677777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 13: LRFD Spec, 45 ft Span, Type 5SB15, 5.2' Bm Spacing, 5" Slab
PROB Opt Design Check for Ex 8 using Opt Design Forms and 1/2" Special Strands
$BEAMSpan Beam  Beam          Beam Slab Slab
$    LabelLabel TypeSpanLengthSpac.ThickWidth LLDF   RH
BEAMFALL  ALL  5SB1543.583    5.2  5.0  5.2  0.441   60
$ANLY     Top Fiber Bot Fiber Ult. Mom  Release   Final
$ANLY     CL Stress CL Stress Required  Strength  Strength
ANLY      2181.     -2572.    1057.     4000.     5000.
$MAT1        MoE                           MoE
$MAT1        of                            of
$MAT1        Beam                          Slab
MAT1         5000.0                        5000.0
$SPEC    X,  where: 0=95/02 Stnd Spec(default), 1=94 Stnd Spec,
$SPEC    |          5=2004-2007 LRFD, 9=2009-2010 LRFD, A=2012 LRFD
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    |(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     54
$STRD Size   RELX TYP AREA Ult Strength
STRD  1/2    LR   SP .167  270
$STPR Strand No
STPR    CL   24
LOCR       2.50
$DBPR Length No
DBPR 3.0      6
LOCR       2.50
DBPR 6.0      2
LOCR       2.50
$LLDF     Shear
$LLDF     LLDF
LLDF      0.441
$ACAM - Camber comparison, input original design info
$     Orig Orig      Orig           Orig
$      No. Ecc       Ecc            strd
$     Strd @End      @CL            size
ACAM    26 5.00      5.00           1/2
```

Example 14: Design of Standard TxGirder

This example shows input for a standard TxGirder. If shear in the end region (between the critical section for shear and the beam end) is a problem (as it would be here were it not for the specified minimum 1250 psi increase in final over initial concrete strength), the user could either specify a minimum gain in concrete strength from f'_{ci} to f'_c to satisfy the shear capacity limit of 0.18* f'_c (as done in this example input) or else specify a shear coefficient for the region of shear greater than the LRFD Specifications limit of 0.18, but no greater than 0.25 (with caveat that the AASHTO Specifications indicate that a strut-and-tie model is required in such cases to determine shear capacity). Note that in previous AASHTO Specifications (and in *PSTRS14*, prior to Ver. 5.0) the coefficient for the shear capacity limit in such end regions was 0.25.

Design Data:

AASHTO LRFD 2007 Specifications with 2004 Losses
Type Tx54 Beam
C/C Bearing Span Length = 118.00' (120' Span)
Beam Spacing = 9.0'
Slab Thickness = 8"
Relative Humidity = 60%
Specified Minimum Concrete Strength Gain Between Release (f'_{ci}) and Final (f'_c)
(Usually it is best to let the program determine the required final concrete strength but in those situations where final strength needs to be higher to meet the end region shear requirements, increasing f'_c can be a relatively easy solution, as long as the upper limit on a practical f'_c value is not broached.)
Specified Coeff. for Nominal Shear Resist. Between Critical Pnt for Shear and Beam End
(0.18 is the default for this coefficient and thus specifying it's values as done in the example input not necessary, but if a larger LLDF for shear or less assumed minimum concrete strength gain were used, 0.18* f'_c would be inadequate and one option would be to raise this coefficient. To do so, the LRFD Specifications requires that a strut-and-tie model be used to determine shear capacity of the beam in this end region.)
Uniform Dead Load on Composite Section (excluding overlay) = 0.132 kip/ft
(two T501 Rails distributed to 5 beams)
Live Load Distribution Factor for Moment = 0.71 (AASHTO LRFD 4.6.2.2.2b-1(k) – conservatively assuming 0 degree skew and n=1.45)
Live Load Distribution Factor for Shear = 1.02 (AASHTO LRFD 4.6.2.2.3a-1(k) – conservatively assuming 45 degree skew and n=1.45)

Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 14: LRFD Spec, 120 ft Span, Tx54, 9' Bm Spa, 8" Slab, 1/2" Strands
PROB Tx Girders Defined as Standard Beams (Min 1250 psi gain of f'c over f'ci)
$Tx54, 1/2" strands
$MAT1        MoE         Min Beam          MoE
$MAT1        of          Conc Str          of
$MAT1        Beam        Gain              Slab
MAT1         5000.0      1250.             5000.0
$OUTP   LF - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF - SF is default and it omits the listed LF tables
```

```
OUTP    LF
$SHRS                                           Coef. For Nom. Shear
$SHRS                                           Resistance Between
$SHRS                 Num.  Bar                 Critical Point
$SHRS    Web width    Legs  Size                and Beam End
SHRS       7.00        2    4                   0.18
$STRD Size
STRD  1/2
$SPEC    X,  where: 0=95/02 Stnd Spec(default), 1=94 Stnd Spec,
$SPEC    |          5=2004-2007 LRFD, 9=2009-2010 LRFD, A=2012 LRFD
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    |(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     54
$LLDF     Shear
$LLDF     LLDF
LLDF      1.02
$BEAMSpan Beam Beam           Beam Slab Comp Mom                      UDL on
$    Spn# Bm#  Type SpanLengthSpac.ThickSlab LLDF    RH               Comp Sec
BEAM ALL  Tx54 TX54 118.00    9.000 8.0 9.0  0.71    60               0.132
```

Example 15: Design of TxGirder with a Non-Standard Strand Grid

This example shows the input for a TxGirder using a non-standard strand grid that is often more efficient when using .6 strands. See Figure 14 and Figure 15 for girder dimensions and strand locations. The beam and loading in this example are the same as the beam designed in **Example 14: Design of Standard TxGirder**. Because of high end shear the minimum increase in Strength Gain Between Release (f'_{ci}) and Final (f'_c) had to be increased slightly over that used in Example 14.

Design Data:

AASHTO LRFD Specifications
Type Tx54 Beam
Strand Size = 0.600

Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 15: LRFD Spec, 120 ft Span, Tx54, 9' Bm Spa, 8" Slab, 1/2" Strands
PROB TxGirder With 0.6" Strands and Non-Standard Strand Grid
$Tx54, 0.6" strands
$MAT1        MoE         Min Beam          MoE
$MAT1        of          Conc Str          of
$MAT1        Beam        Gain              Slab
MAT1         5000.0      1500.             5000.0
$OUTP   LF/ - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF  - SF is default and it omits these tables
OUTP    LF
$STRD Size
STRD  .600
$MSPR Str/RowNo   No   No   No   No   No   No   No   No   No   No   No   No   No
$LOCR Yb  ####.####.####.####.####.####.####.####.####.####.####.####.####.####.
MSPR         10   10   10   10    8    4    2    2    2    2    2    2    2    2
LOCR       2.50 4.50 6.50 8.5010.5012.5014.5016.5018.5020.5022.5024.5026.5028.50
MSPR          2    2    2    2    2    2    2    2    2    2    2
LOCR      30.5032.5034.5036.5038.5040.5042.5044.5046.5048.5050.50
$SPEC    X,  where: 0=95/02 Spec(default), 1=94 Spec, 5=2007 Spec, 9=2009 Spec
$SPEC    |          A=2012 Spec
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    ||(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     54
$LLDF     Shear
$LLDF     LLDF
LLDF      1.02
$BEAMSpan Beam Beam           Beam Slab Comp Mom                     UDL on
$    Spn# Bm#  Type SpanLengthSpac.ThickSlab LLDF    RH              Comp Sec
BEAM ALL  Tx54 TX54 118.00    9.000 8.0 9.0  0.71    60              0.132
```

Example 16: Design of Standard Decked Slab Beam

The purpose of this example is to illustrate the input that is required to design a Standard Decked Slab beam. The design data required is as follows.

Design Data:

AASHTO LRFD Specifications
Type 6DS20 Beam
C/C Bearing Span Length = 48.583′ (50′ ft Span)
Beam Spacing = 6.5′
Relative Humidity = 60%
Uniform Dead Load on Composite Section (due to overlay) = 0.152 kip/ft
Uniform Dead Load on Composite Section (excluding overlay) = 0.191 kip/ft
Moment Live Load Distribution Factor = 0.580 (AASHTO LRFD 4.6.2.2.2b-1(j))
Shear Live Load Distribution Factor = 0.580 (AASHTO LRFD 4.6.2.2.3a-1(j))

Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777778
$234567890123456789012345678901234567890123456789012345678901234567890123456789
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 16: LRFD Spec, 50 ft Span, Type 6DS20, 6.5' Bm Spacing
PROB Standard Decked Slab Beam design using LRFD Specs
$OUTP   LF/ - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF  - SF is default and it omits these tables
OUTP    LF
$MAT1        MoE                           MoE
$MAT1        of                            of
$MAT1        Beam                          Slab
MAT1         5000.0                        5000.0
$SPEC    X,  where: 0=95/02 Spec(default), 1=94 Spec, 5=2007 Spec, 9=2009 Spec
$SPEC    |          A=2012 Spec
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    ||(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     54
$LLDF     Shear
$LLDF     LLDF
LLDF      0.580
$BEAMSpan Beam Beam           Beam Slab Comp Mom             UDL       UDL on
$    LabelLabelType SpanLengthSpac.ThickSlab LLDF    RH      Overlay   Comp Sec
BEAM ALL  ALL  6DS20 48.583   6.5            0.580   60      0.152     0.191
```

Example 17: Design of Standard X Beam

The purpose of this example is to illustrate the input that is required to design a Standard X Beam supporting 44 ft roadway and having Type T551 bridge rails. The design data required is as follows.

Design Data:

AASHTO LRFD Specifications (thru 2009)
Type 5XB40 Beam
C/C Bearing Span Length = 98′ (100′ ft Span)
Beam Spacing = 7.6’
Relative Humidity = 60%
Uniform Dead Load on Composite Section (excluding overlay) = 0.153 kip/ft
Moment Live Load Distribution Factor = 0.540 (AASHTO LRFD 4.6.2.2.2b-1(b))
Shear Live Load Distribution Factor = 0.900 (AASHTO LRFD 4.6.2.2.3a-1(b))

Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Ex 17: LRFD 2009 Spec, 44-ft Rdwy, 100 ft Span, Type 5XB40, 7.6' Bm Spa, 8" Slab
PROB Standard X Beam design using LRFD Specs
$OUTP   LF/ - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF  - SF is default and it omits these tables
OUTP    LF
$MAT1        MoE                            MoE
$MAT1        of                             of
$MAT1        Beam                           Slab
MAT1         5000.0                         5000.0
$SPEC    X,  where: 0=95/02 Spec(default), 1=94 Spec, 5=2007 Spec, 9=2009 Spec
$SPEC    |          A=2012 Spec
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    ||(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     94
$LLDF     Shear
$LLDF     LLDF
LLDF      0.900
$BEAMSpan Beam Beam           Beam Slab Comp Mom            UDL       UDL on
$    LabelLabelType SpanLengthSpac.ThickSlab LLDF    RH     Overlay   Comp Sec
BEAM ALL  ALL  5X40  98.00    7.6  8.0       0.540   60               0.127
```

Example 18: Design of Standard TxGirder Considering Transfer Length

The purpose of this example is to show the input for considering the effects of prestress transfer length. The beam and loading in this example are the same as the beam designed in **Example 1: Design of Standard I Beam**. Comparing *PSTRS14* v 6.0 results using the inputs files of Examples 14 and 18, the benefit of considering transfer length for the been designed is a slight decrease in release and final concrete strengths, with design f'_{ci} being reduced from 5.695 ksi to 5.203 ksi and corresponding design f'_c from 6.945 ksi to 6.843 ksi.

Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 18: LRFD Spec, 120 ft Span, Tx54, 9' Bm Spa, 8" Slab, 1/2" Strands
PROB Example 14, Tx Girders..., Considering Prestress Transfer Lgth Effects
$Tx54, 1/2" strands
$MAT1        MoE         Min Beam          MoE
$MAT1        of          Conc Str          of
$MAT1        Beam        Gain              Slab
MAT1         5000.0      1000.             5000.0
$OUTP   LF/ - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF  - SF is default and it omits these tables
OUTP    LF
$SHRS                                            Coef. For Nom. Shear
$SHRS                                            Resistance Between
$SHRS                  Num.  Bar                 Critical Point
$SHRS    Web width     Legs  Size                and Beam End
SHRS       7.00         2    4                   0.18
$STRD Size
STRD  1/2
$SPEC    X,  where: 0=95/02 Spec(default), 1=94 Spec, 5=2007 Spec, 9=2009 Spec
$SPEC    |          A=2012 Spec
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    ||(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     54
$OPTL                                                              Consider
$OPTL                                                              Effects of
$OPTL                                                              Length of
$OPTL                                                              Prestress
$OPTL                                                              Transfer
$OPTL                                                              |
OPTL                                                               1
$LLDF     Shear
$LLDF     LLDF
LLDF      1.02
$BEAMSpan Beam Beam           Beam Slab Comp Mom                       UDL on
$    Spn# Bm#  Type SpanLengthSpac.ThickSlab LLDF    RH                Comp Sec
BEAM ALL  Tx54 TX54 118.00    9.000 8.0 9.0  0.71    60                0.132
```

Example 19: Life Cycle Camber Report

The purpose of this example is to show the input for a beam design for which the new Life Cycle Camber Report (LCCR) is generated using LCCR default data. The beam and loading in this example are the same as the beam designed in **Example 18: Design of Standard TxGirder Considering Transfer Length**.

Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777778
$234567890123456789012345678901234567890123456789012345678901234567890123456789O
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 19: LRFD Spec, 120 ft Span, Tx54, 9' Bm Spa, 8" Slab, 1/2" Strands
PROB Example 18, Tx Girders..., w/ output of Life Cycle Camber Report (LCCR)
$Tx54, 1/2" strands
$MAT1        MoE         Min Beam         MoE
$MAT1        of          Conc Str         of
$MAT1        Beam        Gain             Slab
MAT1         5000.0      1250.            5000.0
$OUTP   LF/ - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF  - SF is default and it omits these tables
OUTP    LF
$SHRS                                           Coef. For Nom. Shear
$SHRS                                           Resistance Between
$SHRS                 Num.  Bar                 Critical Point
$SHRS   Web width     Legs  Size                and Beam End
SHRS      7.00         2    4                   0.18
$STRD Size
STRD  1/2
$SPEC    X,  where: 0=95/02 Spec(default), 1=94 Spec, 5=2007 Spec, 9=2009 Spec
$SPEC    |          A=2012 Spec
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    ||(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     54
$OPTL                                                             Consider
$OPTL                                                             Effects of
$OPTL                                                             Length of
$OPTL                                                             Prestress
$OPTL                                                             Transfer
$OPTL                                                             |
OPTL                                                              1
$LLDF     Shear
$LLDF     LLDF
LLDF      1.02
$LCCR
LCCR
$BEAMSpan Beam Beam           Beam Slab Comp Mom                        UDL on
$    Spn# Bm#  Type SpanLengthSpac.ThickSlab LLDF    RH                 Comp Sec
BEAM ALL  Tx54 TX54 118.00    9.000 8.0 9.0  0.71    60                 0.132
```

Example 20: Life Cycle Camber Report with User Input Dunnage Location

The purpose of this example is to show the input for a beam design for which the new Life Cycle Camber Report (LCCR) is generated using an input donnage location of 6%, rather than the default of 3%. The beam and loading in this example are the same as the beam designed in **Example 19: Life Cycle Camber Report**.

Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 20: LRFD Spec, 120 ft Span, Tx54, 9' Bm Spa, 8" Slab, 1/2" Strands
PROB Example 19, Tx Girders...LCCR w/ User Input Dunnage Location During Storage
$Tx54, 1/2" strands
$MAT1        MoE         Min Beam          MoE
$MAT1        of          Conc Str          of
$MAT1        Beam        Gain              Slab
MAT1         5000.0      1250.             5000.0
$OUTP   LF/ - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF  - SF is default and it omits these tables
OUTP    LF
$SHRS                                            Coef. For Nom. Shear
$SHRS                                            Resistance Between
$SHRS                 Num.  Bar                  Critical Point
$SHRS    Web width     Legs  Size                 and Beam End
SHRS       7.00         2    4                   0.18
$STRD Size
STRD  1/2
$SPEC    X,  where: 0=95/02 Spec(default), 1=94 Spec, 5=2007 Spec, 9=2009 Spec
$SPEC    |          A=2012 Spec
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    ||(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     54
$OPTL                                                             Consider
$OPTL                                                             Effects of
$OPTL                                                             Length of
$OPTL                                                             Prestress
$OPTL                                                             Transfer
$OPTL                                                             |
OPTL                                                              1
$LLDF     Shear
$LLDF     LLDF
LLDF      1.02
$LCCR
$                                                                     DunnageLoc
$                                                                     %Bm_Length
LCCR                                                                  6.0
$BEAMSpan Beam Beam           Beam Slab Comp Mom                      UDL on
$    Spn# Bm#  Type SpanLengthSpac.ThickSlab LLDF    RH               Comp Sec
BEAM ALL  Tx54 TX54 118.00    9.000 8.0 9.0  0.71    60               0.132
```

The LCCR results of Examples 19 and 20 are summarized below to illustrate the sensitivity of calculated camber values to the distance from end of beam to support locations during storage (for design camber calculations, PSTRS14 assumes that beam length is at all times equal to the center-to-center bearing length). Dunnage location is one of many factors affecting beam camber that are typically unknown at design time and the results given below illustrate why the prediction of beam camber as a single value is an elusive exercise for bridge designers.

```
                    ** OPTIONAL LIFE-CYCLE CAMBER REPORT **

Age of beam during significant events (days):
1a. Release of prestress force to beam ==============================    1.00 ~
1b. Beam placed in storage ==========================================    1.00 ~
2.  Beam placed on bridge bearings (erection) =======================  110.00 *
3.  Load added to non-composite beam (e.g. weight of deck panels) ===  115.00 *
4.  Cast-in-place composite slab added to beam ======================  120.00 ~
5.  Load added to composite section (e.g. weight of rail/overlay)====  180.00 *
6.  End of expected service life ==================================== 27375.00 *

Elastic cambers and deflections (camber is positive; values are in inches):
a. Defl. at release due to beam weight ===================================  -2.87
b. Camber due to prestress force at release ==============================   5.43
c. Camber due to reduced span when placed in storage ====================   0.83
d. Defl. due to increased span length when placed on bridge bearings ====  -0.75
e. Defl. due to load added to non-composite beam (e.g. deck panel. wt.)==   0.00
f. Defl. due to wt. of cast-in-place slab ===============================  -2.75
g. Defl. due to load added to composite section (e.g. rail/overlay wt.)==  -0.15

Time-dependent cambers (inches):
```

Event Listed Above	Days from Release	Camber Before Event	Camber After Event	Days to Next Event	Camber Before Next Event	
1a.	0.00	0.00	2.56	0.00	2.56	EXAMPLE 19
1b.	0.00	2.56	2.98	109.00	5.73	
2.	109.00	5.73	5.35	5.00	5.28	(Distance
3.	114.00	5.28	5.28	5.00	5.27	from physical
4.	119.00	5.27	2.52	60.00	1.93	end of beam
5.	179.00	1.93	1.78	27196.00	1.30	to storage
6.			1.30			support = 3 %)
1a.	0.00	0.00	2.56	0.00	2.56	EXAMPLE 20
1b.	0.00	2.56	3.39	109.00	6.64	
2.	109.00	6.64	5.88	5.00	5.73	(Distance
3.	114.00	5.73	5.73	5.00	5.69	from physical
4.	119.00	5.69	2.94	60.00	2.32	end of beam
5.	179.00	2.32	2.17	27196.00	1.71	to storage
6.			1.71			support = 6 %)

Example 21-23: Design of TxGirder with Minimum Specified f'_{ci} Using Each of Three Prestress Losses Specs for LRFD Designs

This example shows the input for the TxGirder of **Example 14: Design of Standard TxGirder** adjusted by user specified minimum f'_{ci} and considering different prestress losses specs. Traditionally, the f'_{ci} in PSTRS14 has been set to the hard coded value of 4000 psi. However, TxDOT Research Project 0-6374 recommended simplified prestress loss equations that result in higher losses than does the AASHTO LRFD 2004 method for the lower range of f'_{ci}. To effectively compare the three loss methods using PSTRS14 the program has, in Version 6.0, been modified to allow the user to specify minimum f'_{ci} .

Example 21 Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 21: LRFD Spec, 120 ft Span, Tx54, 9' Bm Spa, 8" Slab, 1/2" Strands
PROB Tx Girders Defined as Stnd Bms; Min f'ci of 5800 psi; 2004 AASHTO Losses
$Tx54, 1/2" strands
$MAT1              Min  Min Bm
$MAT1        MoE    f'ci Conc             MoE
$MAT1        of     of   Strgth           of
$MAT1        Beam   Beam Gain             Slab
MAT1         5000.0 5800.1250.            5000.0
$OUTP   LF/ - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF  - SF is default and it omits these tables
OUTP    LF
$SHRS                                            Coef. For Nom. Shear
$SHRS                                            Resistance Between
$SHRS                 Num.  Bar                  Critical Point
$SHRS    Web width    Legs  Size                 and Beam End
SHRS       7.00        2    4                    0.18
$STRD Size
STRD  1/2
$SPEC    X,  where: 0=95/02 Spec(default), 1=94 Spec, 5=2007 Spec, 9=2009 Spec
$SPEC    |          A=2012 Spec
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    ||(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     54
$LLDF     Shear
$LLDF     LLDF
LLDF      1.02
$BEAMSpan Beam Beam          Beam Slab Comp Mom                     UDL on
$    Spn# Bm#  Type SpanLengthSpac.ThickSlab LLDF    RH             Comp Sec
BEAM ALL  Tx54 TX54 118.00    9.000 8.0 9.0  0.71    60             0.132
```

Example 22 Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777778
$2345678901234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 21: LRFD Spec, 120 ft Span, Tx54, 9' Bm Spa, 8" Slab, 1/2" Strands
```

```
PROB Tx Girders Defined as Stnd Bms; Min f'ci of 5800 psi; 2004 AASHTO Losses
$Tx54, 1/2" strands
$MAT1               Min  Min Bm
$MAT1        MoE    f'ci Conc              MoE
$MAT1        of     of   Strgth            of
$MAT1        Beam   Beam Gain              Slab
MAT1         5000.0 5800.1250.             5000.0
$OUTP   LF/ - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF  - SF is default and it omits these tables
OUTP    LF
$SHRS                                            Coef. For Nom. Shear
$SHRS                                            Resistance Between
$SHRS                  Num.  Bar                 Critical Point
$SHRS    Web width     Legs  Size                and Beam End
SHRS       7.00         2    4                   0.18
$STRD Size
STRD  1/2
$SPEC    X,  where: 0=95/02 Spec(default), 1=94 Spec, 5=2007 Spec, 9=2009 Spec
$SPEC    |          A=2012 Spec
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    ||(Design Spec default= 0 for SS & AREMA)
$SPEC    ||(Losses Spec default= 4 for LRFD)
SPEC     57
$LLDF     Shear
$LLDF     LLDF
LLDF      1.02
$BEAMSpan Beam Beam           Beam Slab Comp Mom                     UDL on
$    Spn# Bm#  Type SpanLengthSpac.ThickSlab LLDF    RH              Comp Sec
BEAM ALL  Tx54 TX54 118.00    9.000 8.0 9.0  0.71    60              0.132
```

Example 23 Input:

```
$        1111111111222222222233333333334444444444555555555566666666667777777778
$234567890123456789012345678901234567890123456789012345678901234567890
PSF No    County---------     Highway---     XXXX-XX-XXX  CodedBy
Example 21: LRFD Spec, 120 ft Span, Tx54, 9' Bm Spa, 8" Slab, 1/2" Strands
PROB Tx Girders Defined as Stnd Bms; Min f'ci of 5800 psi; 2004 AASHTO Losses
$Tx54, 1/2" strands
$MAT1               Min  Min Bm
$MAT1        MoE    f'ci Conc              MoE
$MAT1        of     of   Strgth            of
$MAT1        Beam   Beam Gain              Slab
MAT1         5000.0 5800.1250.             5000.0
$OUTP   LF/ - LF outputs tables of moments, shears, and stresses at tenth points
$OUTP   SF  - SF is default and it omits these tables
OUTP    LF
$SHRS                                            Coef. For Nom. Shear
$SHRS                                            Resistance Between
$SHRS                  Num.  Bar                 Critical Point
$SHRS    Web width     Legs  Size                and Beam End
SHRS       7.00         2    4                   0.18
$STRD Size
STRD  1/2
$SPEC    X,  where: 0=95/02 Spec(default), 1=94 Spec, 5=2007 Spec, 9=2009 Spec
$SPEC    |          A=2012 Spec
$SPEC    |Y, where: 0=1994 losses, 4=2004 losses, 7=2007 losses
$SPEC    ||         A=TxDOT 2012 losses
$SPEC    ||(Design Spec default= 0 for SS & AREMA)
```

```
$SPEC     ||(Losses Spec default= 4 for LRFD)
SPEC      5A
$LLDF      Shear
$LLDF      LLDF
LLDF       1.02
$BEAMSpan Beam Beam           Beam Slab Comp Mom                          UDL on
$    Spn# Bm#  Type SpanLengthSpac.ThickSlab LLDF    RH                   Comp Sec
BEAM ALL  Tx54 TX54 118.00    9.000 8.0 9.0  0.71    60                   0.132
```

Comparison of Examples 21 thru 23

The tables below summarize pertinent PSTRS14 results (in terms of beam designs and the losses at centerline) using the input data of Examples 21 thru 23. The optional design data is identical between these examples so is not shown below.

EXAMPLE NO.	LOSSES SPEC	CALC LOSSES at CL	DESIGNED BEAMS (DREPRESSED STRANDS)								
			PRESTRESSING STRANDS							CONCRETE	
			TOTAL					DEPRESSED		RELEASE STRGTH f'ci	MINIMUM 28 DAY COMP STRGTH f'c
			NO.	SIZE	STRGTH fpu	"e" CL	"e" END	NO.	TO		
		(ksi)		(in)	(ksi)	(in)	(in)		(in)	(ksi)	(ksi)
21	AASHTO 2004	59.52	68	1/2	270	16.83	9.83	14	48.5	5.800	7.043
22	AASHTO 2007	45.26	60	1/2	270	17.61	12.94	10	38.5	5.800	7.014
23	TxDOT 2012	57.23	66	1/2	270	17.07	10.16	12	50.5	5.800	6.989

The AASHTO 2007 losses procedure is not recommended for use in design (or analysis) as it provides what is likely an unconservative reduction in the number of strands over that required with the AASHTO 2004 losses procedure.

However, if we modify the input for each example and set the minimum f'_{ci} not to 5800 psi, but instead to the 4000 psi default value, the AASHTO TxDOT 2012 losses spec would actually require an increased number of strands from 68 to 70 and the AASHTO 2007 losses spec would result in virtually the same design as the AASHTO 2004 losses spec.

EXAMPLE NO.	LOSSES SPEC	CALC LOSSES at CL	DESIGNED BEAMS (DREPRESSED STRANDS)								
			PRESTRESSING STRANDS							CONCRETE	
			TOTAL					DEPRESSED		RELEASE STRGTH f'ci	MINIMUM 28 DAY COMP STRGTH f'c
			NO.	SIZE	STRGTH fpu	"e" CL	"e" END	NO.	TO		
		(ksi)		(in)	(ksi)	(in)	(in)		(in)	(ksi)	(ksi)
21	AASHTO 2004	59.61	68	1/2	270	16.83	9.42	14	50.5	5.695	6.945
22	AASHTO 2007	48.87	68	1/2	270	16.83	9.42	14	50.5	5.744	6.994
23	TxDOT 2012	59.50	70	1/2	270	16.55	8.78	16	50.5	5.761	7.011

Though it is counter intuitive to have the design solution result in the same number of strands when losses are less, or to require more strands when losses are essentially the same, this seems to be the result of the way the PSTRS14 design algorithm negotiates the design solution coupled with both the AASHTO 2007 and TxDOT 2012 Losses sensitivity to f'_{ci}.

Appendix C – Optional Design Input Forms

Note: *The Optional Design Input Forms of this appendix illustrate the cards and input fields that are generally used when performing optional designs/checks on the indicated beam types. Additional cards and/or data fields may be needed and employed at users' discretion. When the BEAMF card is used, the ACAM card must be present and must be the last card in the input file.*

Standard Beams with Draped or Straight Strands

Optional Design No. OD-___________
Project No.: ______________________
Contractor: ______________________
Fabricator: ______________________
Plan Sheet No.: __________________

Texas State Department of Transportation (TxDOT)
Prestressed Concrete Optional Design
Draped or Straight, Fully Bonded Strand Pattern
Standard Beam Types
(for PSTRS14 Ver 6.0, September 2015)

Sheet _ of _

Reserve this space for approval stamp

Reason for Rejection:
____
____
____
____
____
____
____

Shop Plan File No. | County | Highway No. | Control-Section-Job

OD#

- -

Structure Name

P R O B | Comments

1 4 6 8 9 11 25 31 40 46 56

Units Card | Input Units | Output Units | Enter "E" for English units and "M" for Metric units

U N I T

1 4 10 15

Beam Card | Beam Type | Span Length C-C Brg. (ft or m) | Bm Spac. (ft or m) | Slab Thick. (in or mm) | Live Load Dist. Factor | Relative Humidity

B E A M F

1 4 16 21 31 36 40 46 50 54

Analysis Card | C.L. Design Stress (psi or Mpa) Top (fct) | Bottom (fcb) | Required Ultimate Moment (k-ft or kN-m) | Fabricator Conc. Strength (psi or Mpa) Release | 28-day

A N L Y

1 4 11 21 31 41 51 60

Strand Card | Strand size (in or mm) | L R (Low-Relaxation) S R (Stress-Relieved) | Strand Ultimate Strength (ksi or MPa)

S T R D

1 4 7 10 14-15 26 30

Material #1 Card | Mod. Of Elasticity of Beam (ksi or MPa) | Mod. Of Elasticity of Slab (ksi or Mpa) | Slab 28-Day Conc. Strength (psi or kPa)

M A T 1 | 5 0 0 0 | 5 0 0 0

1 4 11 20 41 51 55

Spec Card | DESIGN SPEC * | LOSSES SPEC # | Live Load Type

S P E C

1 4 10 12 15

-AASHTO Specifications Code
0 or Blank = 1995 AASHTO Standard Specifications
1 = 1994 AASHTO Standard Specifications
5 = 2007 AASHTO LRFD Specifications
9 = 2009 & 2010 AASHTO LRFD Specifications
A = 2012 AASHTO LRFD Specificactions

#-AASHTO Losses Specifications Code
For Standard Specifications
0 or Blank = 1994 Losses
For LRFD Specifications
4 or blank = 2004 Losses
7 = 2007 Losses
A = TxDOT 2012 Losses

Optional Design No. OD-___________
Project No.: ______________________
Contractor: ______________________
Fabricator: ______________________
Plan Sheet No.: __________________

Texas State Department of Transportation (TxDOT)
Prestressed Concrete Optional Design
Draped or Straight, Fully Bonded Strand Pattern
Standard Beam Types
(for PSTRS14 Ver 6.0, September 2015)

Sheet _ of _

Centerline Strand
Pattern Card

Strands per Row / Distance from Bottom (in or mm)

S T P R | C L
L O C R

1 4 11 16 21 26 31 36 41 46 51 56 61 66 70 76 80

End Strand
Pattern Card

Strands per Row / Distance from Bottom (in or mm)

S T P R | E D
L O C R

1 4 11 16 21 26 31 36 41 46 51 56 61 66 70 76 80

**Shear LLDF
Card

Shear Live Load
Distribution factor

L L D F | 0 . 1

1 4 11 15

**Shear LLDF Card only required for LRFD optional designs. Shear live load very rarely effects the optional flexural design, and so an arbitrarily low value (0.1) is used. If a shear live load distribution factor is provided in the contract plans, input the provided value.

User Defined
Design Factor
Card

Compression Allowable
Coefficient
(At Release)

U F A C

1 4 26 30

Transformed
Steel Card

Bar Area
(in^2 or mm^2)

Distance from
Bottom (in or mm)

T R N F | C 1

1 4 9 11 16 20

Original Beam
Camber Card

No. of
Strands

End Eccentricity
(in or mm)

C.L. Eccentricity
(in or mm)

Strand Size
(in or mm)

L R
or
S R

7 W
or
C P

Strnd
Area
(in^2 or mm^2)

Strnd
Ult.
Strength
(ksi or Mpa)

Concrete
Final Strength
of Original Beam
(psi or Mpa)

A C A M

1 4 8 11 21 30 37 40 44-45 51 56 60 61 70

Standard Beams with Partially Debonded Strands

Optional Design No. OD-___________
Project No.: ______________________
Contractor: ______________________
Fabricator: ______________________
Plan Sheet No.: ___________________

Texas State Department of Transportation (TxDOT)
Prestressed Concrete Optional Design
Partially Debonded Strand Pattern
Standard Beam Types
(for PSTRS14 Ver 6.0, September 2015)

Sheet _ of _

Reserve this space for approval stamp

Reason for Rejection:
____
____
____
____
____
____

Shop Plan File No. | County | Highway No. | Control-Section-Job

OD#
– –
Structure Name
P R O B
Comments

1 4 6 8 11 25 31 40 46 56

Units Card | Input Units | Output Units

Enter "E" for English units and "M" for Metric units

U N I T

1 4 10 15

Beam Card | Beam Type | Span Length C-C Brg. (ft or m) | Bm Spac. (ft or m) | Slab Thick. (in or mm) | Live Load Dist. Factor | Relative Humidity

B E A M F

1 4 16 21 31 36 40 46 50 54

Analysis Card | C.L. Design Stress (psi or Mpa) Top (fct) Bottom (fcb) | Required Ultimate Moment (k-ft or kN-m) | Fabricator Conc. Strength (psi or Mpa) Release 28-day

A N L Y

1 4 11 21 31 41 51 60

Strand Card | Strand size (in or mm) | L R S R | Strand Area (in^2 or mm^2) | Strand Ultimate Strength (ksi or MPa) | (With Debonding) (No Debonding) | W D N D

S T R D

1 4 7 10 14-15 21 26 30 41 51 61 69-70

Material #1 Card | Mod. Of Elast. of Beam (ksi or MPa) | Mod. of Elast. of Slab (ksi or Mpa) | Slab 28-Day Conc. Strength (psi or kPa) | Mod. of Elast. of Shear Key[1] (ksi or Mpa) | Shear Key 28-Day Conc Strength[1] (psi or MPa)

M A T 1 5 0 0 0 5 0 0 0 5 0 0 0

1 4 11 20 41 51 55 61 71 75

Spec Card | DESIGN SPEC * | LOSSES SPEC # | Live Load Type

S P E C

1 4 10 12 15

-AASHTO Specifications Code
0 or Blank = 1995 AASHTO Standard Specifications
1 = 1994 AASHTO Standard Specifications
5 = 2007 AASHTO LRFD Specifications
9 = 2009 & 2010 AASHTO LRFD Specifications
A = 2012 AASHTO LRFD Specificactions

#-AASHTO Losses Specifications Code
For Standard Specifications
0 or Blank = 1994 Losses
For LRFD Specifications
4 or blank = 2004 Losses
7 = 2007 Losses
A = TxDOT 2012 Losses

Optional Design No. OD-___________
Project No.: _____________________
Contractor: ______________________
Fabricator: ______________________
Plan Sheet No.: __________________

Texas State Department of Transportation (TxDOT)
Prestressed Concrete Optional Design
Partially Debonded Strand Pattern
Standard Beam Types
(for PSTRS14 Ver 6.0, September 2015)

Sheet _ of _

Centerline Strand
Pattern Card Strands per Row / Distance from Bottom (in or mm)

S T P R C L
L O C R
1 4 11 16 21 26 31 36 41 46 51 56 61 66 70 76 80

Debonded Strand (Must enter DBPR/LOCR cards in order from the end of the beam towards the centerline)
Pattern Card Debonded Length (ft or m) Debonded Strands per Row / Distance from Bottom (in or mm)

D B P R
L O C R
1 4 11 16 21 26 31 36 41 46 51 56 61 66 70 76 80

Debonded Strand (Must enter DBPR/LOCR cards in order from the end of the beam towards the centerline)
Pattern Card Debonded Length (ft or m) Debonded Strands per Row / Distance from Bottom (in or mm)

D B P R
L O C R
1 4 11 16 21 26 31 36 41 46 51 56 61 66 70 76 80

Debonded Strand (Must enter DBPR/LOCR cards in order from the end of the beam towards the centerline)
Pattern Card Debonded Length (ft or m) Debonded Strands per Row / Distance from Bottom (in or mm)

D B P R
L O C R
1 4 11 16 21 26 31 36 41 46 51 56 61 66 70 76 80

Debonded Strand (Must enter DBPR/LOCR cards in order from the end of the beam towards the centerline)
Pattern Card Debonded Length (ft or m) Debonded Strands per Row / Distance from Bottom (in or mm)

D B P R
L O C R
1 4 11 16 21 26 31 36 41 46 51 56 61 66 70 76 80

Debonded Strand (Must enter DBPR/LOCR cards in order from the end of the beam towards the centerline)
Pattern Card Debonded Length (ft or m) Debonded Strands per Row / Distance from Bottom (in or mm)

D B P R
L O C R
1 4 11 16 21 26 31 36 41 46 51 56 61 66 70 76 80

Optional Design No. OD-___________
Project No.: ______________________
Contractor: ______________________
Fabricator: ______________________
Plan Sheet No.: ___________________

Texas State Department of Transportation (TxDOT)
Prestressed Concrete Optional Design
Partially Debonded Strand Pattern
Standard Beam Types
(for PSTRS14 Ver 6.0, September 2015)

Sheet _ of _

```
Optional        W K (With Shear Key, For Box Beam Only)
Card            N K (No Shear Key)

|O P T L| | | | |  |
 1     4         9 10

**Shear LLDF       Shear Live Load
Card               Distribution factor

|L L D F| | | | | |    0 . 1|
 1     4           11      15

User Defined                                Compression Allowable
Design Factor                                    Coefficient
Card                                            (At Release)

|U F A C| | | ... | | |        .|
 1     4                                     26       30

Transformed          Bar Area    Distance from
Steel Card        (in2 or mm2)  Bottom (in or mm)

|T R N F|        |C 1|   .    |   .    |
 1     4          9  11        16      20
```

**Shear LLDF Card only required for LRFD optional designs. Shear live load very rarely effects the optional flexural design, and so an arbitrarily low value (0.1) is used. If a shear live load distribution factor is provided in the contract plans, input the provided value.

Original Beam Camber Card	No. of Strands	End Eccentricity (in or mm)	C.L. Eccentricity (in or mm)	Strand Size (in or mm)	L R or S R	7 W or C P	Strnd Area (in^2 or mm^2)	Strnd Ult. Strength (ksi or Mpa)	Concrete Final Strength of Original Beam (psi or Mpa)
A C A M		.	.				.	.	.
1 – 4	8	11 – 21	21 – 30	37 – 40	44-45		51 – 56	56 – 60	61 – 70

Non-Standard Beams with Partially Debonded Strands

Optional Design No. OD-__________
Project No.: ____________________
Contractor: _____________________
Fabricator: _____________________
Plan Sheet No.: _________________

Texas State Department of Transportation (TxDOT)
Prestressed Concrete Optional Design
Partially Debonded Strand Pattern
Non-**Standard Beams**
(for PSTRS14 Ver 6.0, September 2015)

Sheet _ of _

Shop Plan File No. | County | Highway No. | Control-Section-Job

OD#

Structure Name

Comments

P R O B

1 4 6 8 9 11 25 31 40 46 56

Reserve this space for approval stamp

Reason for Rejection:
____
____
____
____
____
____

Units Card | Input Units | Output Units

Enter "E" for English units and "M" for Metric units

U N I T

1 4 10 15

Beam Card | Beam Type | Span Length C-C Brg. (ft or m) | Bm Spac. (ft or m) | Slab Thick. (in or mm) | Live Load Dist. Factor | Relative Humidity

B E A M F

1 4 16 21 31 36 40 46 50 54

Analysis Card | C.L. Design Stress (psi or Mpa) Top (fct) | Bottom (fcb) | Required Ultimate Moment (k-ft or kN-m) | Fabricator Conc. Strength (psi or Mpa) Release | 28-day

A N L Y

1 4 11 21 31 41 51 60

Strand Card | Strand size (in or mm) | L R S R | Strand Area (in^2 or mm^2) | Strand Ultimate Strength (ksi or MPa) | (With Debonding) (No Debonding) | W D N D

S T R D

1 4 7 10 14-15 21 26 30 41 51 61 69-70

Material #1 Card | Mod. Of Elasticity, E of Beam (ksi or MPa) | E of Slab (ksi or Mpa) | Slab 28-Day Conc. Strength (psi or kPa)

M A T 1 | 5 0 0 0 | 5 0 0 0

1 4 11 20 31 41 51 55

Spec Card | DESIGN SPEC * | LOSSES SPEC # | Live Load Type

S P E C

1 4 10 12 15

-AASHTO Specifications Code
0 or Blank = 1995 AASHTO Standard Specifications
1 = 1994 AASHTO Standard Specifications
5 = 2007 AASHTO LRFD Specifications
9 = 2009 & 2010 AASHTO LRFD Specifications
A = 2012 AASHTO LRFD Specificactions

#-AASHTO Losses Specifications Code
For Standard Specifications
0 or Blank = 1994 Losses
For LRFD Specifications
4 or blank = 2004 Losses
7 = 2007 Losses
A = TxDOT 2012 Losses

Optional Design No. OD-___________
Project No.: ______________________
Contractor: _______________________
Fabricator: _______________________
Plan Sheet No.: ___________________

Texas State Department of Transportation (TxDOT)
Prestressed Concrete Optional Design
Partially Debonded Strand Pattern
Non-**Standard Beams**
(for PSTRS14 Ver 6.0, September 2015)

Sheet _ of _

------------------------- SERVICEABILITY --------------------------------------- | ----------------------- ULTIMATE --------------------------

Non-Standard Cross-Section Card 1	Area of Beam (in^2 or mm^2)	Yb of Beam (in or mm)	I of Beam (in^4 or mm^4*E6)	Width of Compression (in or mm)	Max. Depth of Compression Zone (in or mm)	Yb of Compression Zone (in or mm)
N S C S						

Card 2

N S C S

Card "n"

N S C S

1 4 11 21 31 41 51 61 71 80

Centerline Strand Pattern Card

Strands per Row / Distance from Bottom (in or mm)

S T P R C L

L O C R

1 4 11 16 21 26 31 36 41 46 51 56 61 66 70 76 80

Debonded Strand (Must enter DBPR/LOCR cards in order from the end of the beam towards the centerline)
Pattern Card Debonded Length (ft or m) Debonded Strands per Row / Distance from Bottom (in or mm)

D B P R

L O C R

1 4 11 16 21 26 31 36 41 46 51 56 61 66 70 76 80

Debonded Strand
Pattern Card Debonded Length (ft or m) Debonded Strands per Row / Distance from Bottom (in or mm)

D B P R

L O C R

1 4 11 16 21 26 31 36 41 46 51 56 61 66 70 76 80

Optional Design No. OD-___________
Project No.: ______________________
Contractor: ______________________
Fabricator: ______________________
Plan Sheet No.: __________________

Texas State Department of Transportation (TxDOT)
Prestressed Concrete Optional Design
Partially Debonded Strand Pattern
Non-**Standard Beams**
(for PSTRS14 Ver 6.0, September 2015)

Sheet _ of _

Debonded Strand Pattern Card — Debonded Length (ft or m) — Debonded Strands per Row / Distance from Bottom (in or mm)

D B P R
L O C R

1 4 11 16 21 26 31 36 41 46 51 56 61 66 70 76 80

Debonded Strand Pattern Card — Debonded Length (ft or m) — Debonded Strands per Row / Distance from Bottom (in or mm)

D B P R
L O C R

1 4 11 16 21 26 31 36 41 46 51 56 61 66 70 76 80

Debonded Strand Pattern Card — Debonded Length (ft or m) — Debonded Strands per Row / Distance from Bottom (in or mm)

D B P R
L O C R

1 4 11 16 21 26 31 36 41 46 51 56 61 66 70 76 80

**Shear LLDF Card — Shear Live Load Distribution factor

L L D F — 0 . 1

1 4 11 15

**Shear LLDF Card only required for LRFD optional designs. Shear live load very rarely effects the optional flexural design, and so an arbitrarily low value (0.1) is used. If a shear live load distribution factor is provided in the contract plans, input the provided value.

User Defined Design Factor Card — Compression Allowable Coefficient (At Release)

U F A C

1 4 26 30

Transformed Steel Card — Bar Area (in^2 or mm^2) — Distance from Bottom (in or mm)

T R N F — C 1

1 4 9 11 16 20

Original Beam Camber Card	No. of Strands	End Eccentricity (in or mm)	C.L. Eccentricity (in or mm)	Strand Size (in or mm)	L R or S R	7 W or C P	Strnd Area (in^2 or mm^2)	Strnd Ult. Strength (ksi or Mpa)	Concrete Final Strength of Original Beam (psi or Mpa)
A C A M									
1 4	8	11	21 30	37 40	44-45		51	56 60	61 70

Non-Standard Beams with Draped or Straight Strands

Optional Design No. OD-___________
Project No.: _____________________
Contractor: ______________________
Fabricator: ______________________
Plan Sheet No.: __________________

Texas State Department of Transportation (TxDOT)
Prestressed Concrete Optional Design
Draped or Straight, Fully Bonded Strand Pattern
Non-**Standard Beams**
(for PSTRS14 Ver 6.0, September 2015)

Sheet _ of _

Reserve this space for approval stamp

Reason for Rejection:
____
____
____
____
____
____

Shop Plan File No. | County | Highway No. | Control-Section-Job

OD# | – –

Structure Name

P R O B | Comments

1 4 6 8 9 11 25 31 40 46 56

Units Card | Input Units | Output Units | Enter “E” for English units and “M” for Metric units

U N I T

1 4 10 15

Beam Card | Beam Type | Span Length C-C Brg. (ft or m) | Bm Spac. (ft or m) | Slab Thick. (in or mm) | Live Load Dist. Factor | Relative Humidity

B E A M F

1 4 16 21 31 36 40 46 50 54

Analysis Card | C.L. Design Stress (psi or Mpa) Top (fct) | Bottom (fcb) | Required Ultimate Moment (k-ft or kN-m) | Fabricator Conc. Strength (psi or Mpa) Release | 28-day

A N L Y

1 4 11 21 31 41 51 60

Strand Card | Strand size (in or mm) | L R S R | Strand Area (in^2 or mm^2) | Strand Ultimate Strength (ksi or MPa)

S T R D

1 4 7 10 14-15 21 26 30

Material #1 Card | Mod. Of Elasticity, E of Beam (ksi or MPa) | E of Slab (ksi or Mpa) | Slab 28-Day Conc. Strength (psi or kPa)

M A T 1 | 5 0 0 0 | 5 0 0 0

1 4 11 20 31 41 51 55

Spec Card | DESIGN SPEC * | LOSSES SPEC # | Live Load Type

S P E C

1 4 10 12 15

***-AASHTO Specifications Code**
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#-AASHTO Losses Specifications Code
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Optional Design No. OD-___________
Project No.: ______________________
Contractor: _______________________
Fabricator: _______________________
Plan Sheet No.: ___________________

Texas State Department of Transportation (TxDOT)
Prestressed Concrete Optional Design
Draped or Straight, Fully Bonded Strand Pattern
Non-**Standard Beams**
(for PSTRS14 Ver 6.0, September 2015)

Sheet _ of _

Non-Standard Cross-Section Card 1

SERVICEABILITY: Area of Beam (in^2 or mm^2); Yb of Beam (in or mm); I of Beam (in^4 or mm^4*E6)

ULTIMATE: Width of Compression (in or mm); Max. Depth of Compression Zone (in or mm); Yb of Compression Zone (in or mm)

N S C S

Card 2

N S C S

Card "n"

N S C S

1 4 11 21 31 41 51 61 71 80

Centerline Strand Pattern Card

Strands per Row / Distance from Bottom (in or mm)

S T P R　C L

L O C R

1 4 11 16 21 26 31 36 41 46 51 56 61 66 70 76 80

End Strand Pattern Card

Strands per Row / Distance from Bottom (in or mm)

S T P R　E D

L O C R

1 4 11 16 21 26 31 36 41 46 51 56 61 66 70 76 80

**Shear LLDF Card

Shear Live Load Distribution factor

L L D F　0 . 1

1 4 11 15

**Shear LLDF Card only required for LRFD optional designs. Shear live load very rarely effects the optional flexural design, and so an arbitrarily low value (0.1) is used. If a shear live load distribution factor is provided in the contract plans, input the provided value.

User Defined Design Factor Card

Compression Allowable Coefficient (At Release)

U F A C

1 4 26 30

Transformed Steel Card

Bar Area (in^2 or mm^2)　Distance from Bottom (in or mm)

T R N F　C 1

1 4 9 11 16 20

Optional Design No. OD-___________
Project No.: ______________________
Contractor: ______________________
Fabricator: ______________________
Plan Sheet No.: __________________

Texas State Department of Transportation (TxDOT)
Prestressed Concrete Optional Design
Draped or Straight, Fully Bonded Strand Pattern
Non-**Standard Beams**
(for PSTRS14 Ver 6.0, September 2015)

Sheet _ of _

Original Beam Camber Card	No. of Strands	End Eccentricity (in or mm)	C.L. Eccentricity (in or mm)	Strand Size (in or mm)	L R or S R	7 W or C P	Strnd Area (in^2 or mm^2)	Strnd Ult. Strength (ksi or Mpa)	Concrete Final Strength of Original Beam (psi or Mpa)
A C A M		.	.				.	.	.
1 4	8 11	21	30	37 40	44-45	51	56	60 61	70

FILE HISTORY

Initials	Date	Description
TEB	2007-MAR-30	Finalized for release 4.1 and began File History.
TEB	2007-APR-26	Replaced **Standard Beams with Draped or Straight Strands** section in Appendix C with correct input forms.
TEB	2007-DEC-21	Finalized changes for release 4.2.
TEB	2009-OCT-01	Draft changes for release 5.0.
TEB	2010-APR-15	Finalized changes for release 5.0.
TEB	2010-MAY-07	Made additional changes for release 5.0.
TEB	2010-OCT-19	Finalized changes for release 5.1.
TEB	2010-OCT-26	Correction made to Appendix C for release 5.1.
TEB	2010-NOV-12	Finalized changes for release 5.2.
TEB	2016-FEB-22	Finalized changes for release 6.1.